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PHOTO BY R.T. JACKSON

MODERN HIGH-PRESSURE GAS COMPRESSOR

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HOW SLATE IS QUARRIED

The greatest advance in slate production in late years was the adoption of the wire saw. An endless wire cable, mechanically drawn across a block between sheave wheels on fixed tension posts, carries wetted sand abrasive which makes a clean, unwasteful cut faster than can be done by other means. Above is shown a tension post with its sheave wheels for directing the wire. The cut has progressed to a level even with the bottom of the lower wheel, from which the wire may be seen entering the face of the wall. Where one end of a cut is not in the clear, a hole must be made for the tension post. This is done with a "Calyx" core drill such as that shown at the right. This drill speedily takes a 36-inch core, a section of which may be seen at the feet of the workmen at the right of the rig. In the Chapman quarries, such holes are customarily carried to a depth of 16 feet, which permits the extraction of blocks of slate 14 feet thick.

CHAPMAN QUARRIES FROM THE AIR

These huge pits were almost 90 years in the making. From them have come slate roofs to be found in all sections of the country and some abroad. On the right bank can be seen the head towers of the various cableways, and behind each is the building that houses its hoisting machinery. The largest structure is the mill, and beyond it are stock piles of roofing slates. At the upper right is the Village of Chapman Quarries, all of whose residents are dependent upon this enterprise. Some of the houses have slate roofs that were laid more than 70 years ago.

Slate Producers for 88 Years

Chapman Quarries in Pennsylvania Are a Source of High-Quality Roofing Material

RALPH H. BUTZ

AFTER working in the Welsh quarries of Lord Penrhyn during his youth and early manhood, William Chapman came to America in 1837. He prospected the slate districts of Virginia and Pennsylvania for a number of years, and then, during the period 1846-1850, opened the Chapman "hard-vein"* quarries in Northampton County, Pa. He worked them continuously until March, 1864, when he incorporated the Chapman Slate Company, which has operated them ever since. More than 2,000,000 squares of roofing slate—in excess of 200,000,000 square feet—have been manufactured there, and many roofs from 50 to 80 years old, still in fine condition, are an indication of its quality.

Geologists have termed slate "the miracle stone," asserting that it took nature 500,000,000 years to produce the Pennsylvania blue-gray variety. To attempt to reproduce it by laboratory methods would make a slate roof cost many times more than the rest of the building, instead of less than 5 per cent of the total as is now the case.

Slate is a metamorphic rock. It originated as silt deposited on the floor of a lake or sea, probably at the shore line. Nature subjected this silt to long-continued pressure and heat, until the entire mass was compressed and welded into dense, fine-grained rock. Even then it would not have been slate, and it certainly could never have been manufactured into useful slabs for a few cents a square foot had not a tremendous secondary pressure produced the miracle of cleavage.

Cleavage is the distinctive characteristic of slate. Because of it this rock can be split cleaner and better than even the finest of comb-grained wood. A second direction of fracture or scallop, usually at right angles to the slaty cleavage, is called the grain. Roofing slates are commonly split so that the length of the slate runs with the grain. With only a chisel and mallet, slate can be divided into shingles so smooth and even that when properly laid on a roof they are weathertight against the worst storms. Moreover, such rock shingles do not warp or twist as those of wood or artificial materials sometimes do. In some slate the cleavage plane runs parallel to the bedding plane, but in Pennsylvania slate it is always at an angle, occasionally even at a right angle, thus indicating that the rock was subjected not only to vertical pressure but also to equally powerful side pressure.

The nature of the surface after splitting is dependent upon the character of the rock from which it is quarried. Many slates split to a smooth, practically even and uniform surface, while others are somewhat rough and uneven. The two types are designated by the trade as "smooth texture" and "rugged texture."

Roofing slate, being a natural product,

varies in quality from vein to vein and quarry to quarry. This variation is not always apparent from its appearance, as all Pennsylvania slate is very similar in color and texture. It is probably owing to this lack of uniformity, or, rather, because there has not been available information on which to base satisfactory specifications, that slate has not had the wide application that it deserves.

In all the slate deposits of Lehigh and Northampton counties there are present two types of narrow beds. These are known to quarrymen as hard veins or ribbons, depending upon the characteristics of the material composing them. Thus, in the quarries of the Chapman Slate Company, for example, the bedding is what is known as the hard-vein type. These veins are composed, for the most part, of very stable silicon minerals, which make them harder and stronger than the main body of the slate. The great compression through which this slate passed during its formation pressed these once thicker beds into narrow bands. Although they run through the slate, they do not detract from its value in any way, in fact, it is claimed that their presence enhances the appearance of the slate from an architectural standpoint.

The ribbons are of similar origin and formation, but different in mineral content. Some ribbons are softer and considerably darker than the main body of the slate and do not contain the stable silicon minerals found in the hard veins. Others are favored with harder minerals and, as a result, give more satisfactory service. Thus, while hard-vein slate is equal to the best clear slate, this is not usually true of ribbon slate.

An old rule-of-thumb test of the value of slate was that of "ringing," balancing the slate on the finger tips and then striking it with a lead pencil or other light article. A clear bell-like tone denoted a fine slate and was a rough means of determining the absorption of freshly quarried stone. Another test was made by suspending a slate between two bricks and standing upon it to show its high strength and toughness, and still another by breathing upon the slate. If it then gave off a strong claylike smell it was not considered so good as a slate with only a faint odor of clay. These were rough tests and, while not infallible, were a means of indicating quality. They are still applied in England and Wales.

No doubt the insufficiency of the available data was a leading reason why architects and engineers formerly found great difficulty in writing satisfactory specifications for slate. In recent years the industry has been devoting time and energy in an effort to discover better methods of determining and making known the essential facts that have a bearing on quality.

The decision as to what constitutes good roofing slate has resolved itself into the measurement of three separate characteristics: the modulus of rupture, the amount of absorption, and the degree of freedom from acid penetration. The modulus of rupture indicates the strength of slate and discloses whether or not it will withstand handling and the natural stresses and strains to which a roof is subjected. The absorption and acid tests are supposed to provide an index as to its weathering qualities, although the value of an acid test as a true measure of resistance to the elements still remains to be proved. These tests are now the basis of most U. S. Government specifications and are also being made use of by the various state governments. In all of them, slate from

SPLITTING BY GOUGING

Blocks of slate about 12 inches thick, up to 4 feet wide, and as much as 30 feet long, are hoisted from the quarry and hauled to the mill for working. The practice is to work only fresh stone, as it can be handled better and makes superior products. Accordingly, quarrying is done only when there is a need for slate in the mill, and all departments are thus either working or are idle. A block is first split longitudinally or grainwise and at right angles to the cleavage, which is parallel with the floor in the pictures. The workman, or slater, first cuts a "gouge" into the end of the block, as shown at the left. He then strikes a few blows upon a broad-end chisel such as that resting on the hammer in the picture above, holding it in the gouge and on a line with the desired split. This serves to cleave the block, as illustrated. An expert workman can control the course of the cut within an inch or two of a straight line. If it shows signs of veering from the desired course, he can turn it back by changing the direction of the force of his blows.

the Chapman quarries has attained a high rating.

The slate belt in Pennsylvania contains the largest and richest deposits known in America. Extending through Lehigh and Northampton counties, it is approximately 40 miles long and five miles wide. Within this area but a small portion of the slate quarried is of the blue-black, hard-vein variety, of which the Chapman quarries are the largest producers.

In reporting upon a recent analysis of American roofing slate, the National Slate Association designated this particular stone as "exceptionally hard durable slate having one or more hard veins running across the slate. These veins produce a texture and color effect very much to be desired. The color tone grows darker with exposure to the elements."

The specifications for commercial standard roofing slates, in accordance with the grading standards of the National Slate Association, describe hard-vein slate as follows:

"Smooth Texture" Slate—Reasonably smooth straight cleavage full length of slate both front and back. The maximum bend shall not exceed ¼ inch in lengths up to 16 inches, nor exceed ⅜ inch in lengths from 16 to 24 inches. Surface shall be free from knots and knurls that in any way interfere with the safe conveyance or the laying of the slate on the roof. Corners—Reasonably full corners on exposed ends. No broken corners on covered ends that would sacrifice nailing strength, or the laying of a watertight slate roof. Thickness—Approximately 3/16 inch. Weight—700 to 750 pounds per square. (A square is sufficient slate to cover a roof area 100 feet square.)

"Rugged Texture" Slate—Same quality as Smooth Texture, but having a rougher surface with the veins showing more prominently. Not quite so uniform in thickness as Smooth Texture Slate. Weight—725 to 775 pounds per square."

A petrographic analysis of slate is the only well-established method of determining its mineral constituents, and, accordingly, furnishes the most exact means of definitely classifying it.

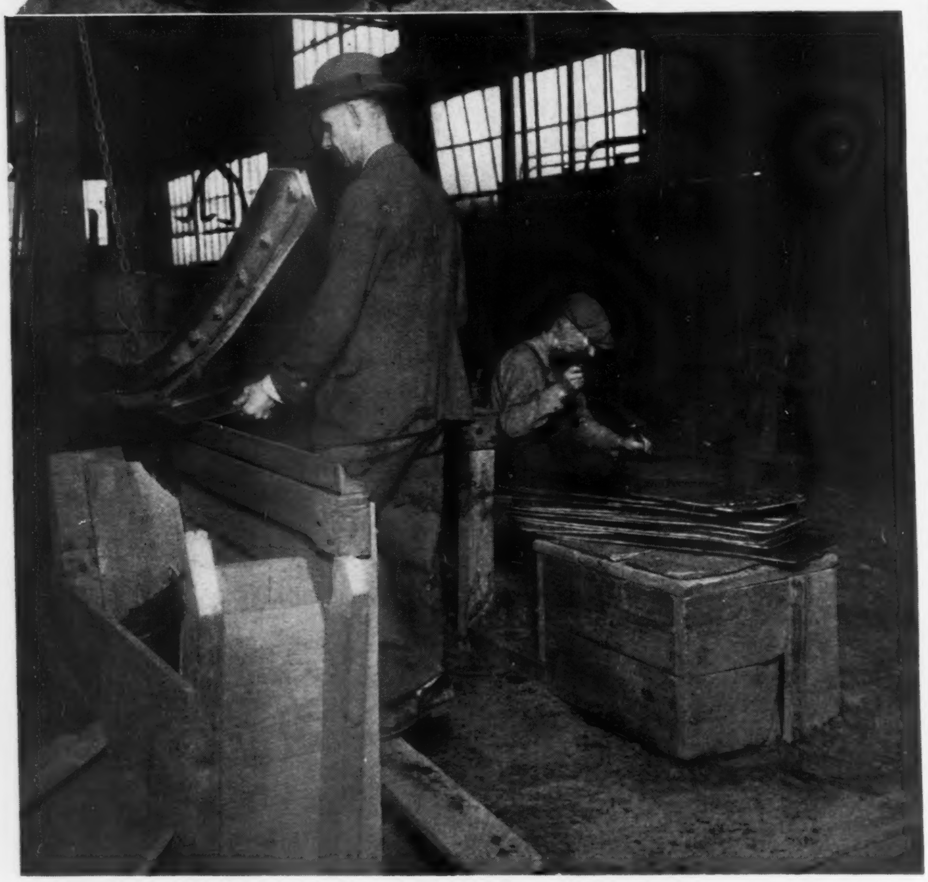
When William Chapman first opened his quarry, the extraction of slate was largely a hand-to-hand struggle between man and rock. The quarrymen had little in the way of mechanical aid except blasting powder. To get the first workable opening in the vein, technically known as a "sink," there was nothing to do but drill and blast, drill and blast, the drilling being a very tedious procedure with old hand drills.

Once a sink was cleared, production began. The aim was to place and to time the blasts so as to cut rather than to destroy the rock. Even in the hands of expert workmen it was crude quarrying, so crude that much fine rock was shattered and thus lost its commercial value. Evidences of this wastage are apparent today as one views the mountains of fragmented rock of fine quality in the vicinity of the quarries.

The first real advance in slate quarrying came about 1890 with the introduction of the channeling machine: the next when the air drill was introduced in 1908. The channeling machine enabled quarrymen to free comparatively large masses of rock with much less breakage than was caused by the old blasting method. However, as the quarry went deeper, trouble was experienced with the shattering of rock across the normal cleavage planes. It was thought at first that this was attributable to water, the rock already having been freed from side or end pressure by the channeling machine. Experience has shown, however, that there is also an upward thrust in very deep quarries, and that it is this pressure which causes the shattering referred to.

FURTHER REDUCING THE BLOCK

One of the two long slabs produced by the gouging process is laid with the cleavage perpendicular to the floor. It is then split as shown above. To reduce each of the resulting pieces into sections, the slater next cuts a notch in one edge across the cleavage, this process being termed "nicking." The slab is next placed with the notched face on the floor and struck a blow with a heavy pig-hickory mallet. This produces a jagged but symmetrical break such as that shown at the right.



FINAL OPERATIONS

Having reduced the block to sections that can be readily handled, the slater, with a wooden mallet and thin knife-like tools which he lubricates before each use with tallow or lard, splits them into sheets about 3/16 inch thick, as shown above. If part of a piece thus formed is below standard, he "picks" across it with the corner of his tool, making a series of indentations as seen in the center picture. The piece is then broken at that line, and the good portion is ready for trimming.

As illustrated at the left, the trimming is done with a knife operated by a foot treadle and suspended by a chain from the end of a sassafrass beam overhead—this wood, it was found, having the most satisfactory spring for raising the knife after each cut. Power-operated cutters were installed when the present mill was built in 1928, but the slaters could not get used to this departure, and the traditional sassafrass springs were restored. The line on which the knife descends is offset about half an inch from the steel support on which the outer end of the slate rests while being trimmed. This gives the desired beveled edge on the shingles.

During all the processing operations that have been pictured, except the gouging and cutting, the edge or face that is being worked is moistened with water by means of a dauber. This not only facilitates breaking, but also darkens the color of the slate and thereby enables the workmen better to observe the course of the fractures.

Slaters working in pairs, and paid on a piecework basis, perform all the successive steps required to reduce a quarry block to shingles. Each pair formerly occupied a separate leanto or shanty. Although 40 men now work in one steel-frame building, the terminology has persisted and each of its twenty stations is still called a shanty. Most of the slate workers grew up in the section where they live, and their fathers and grandfathers before them did the same things they now do and in much the same way.

SLATE-SHINGLE STORAGE

Finished shingles or "slates," as they are termed in the industry, are stored in the open air until they are shipped. Each of these piles contains shingles of a different size. They are stocked in sizes of from 6x12 inches to 14x24 inches, there being four widths of each length. Other sizes are made to order, some of them ranging up to 36 inches long. The building in the background at the left is a slater's shanty.

This thrust is the result of the weight of the surrounding mass of rock.

The greatest advance in quarrying methods was brought about with the introduction of the wire saw, which is threatening to supersede the channeling machine in all slate quarries. It offers several advantages—it is quicker, more economical, and more flexible than the older equipment. With the wire saw it is possible to free the working rock from the main body of the vein and to make cross cuts and side cuts, thus simplifying and facilitating the removal of the rock. The rock is now cut into blocks of much better shape and size while in the quarry, reducing wastage and handling on the banks. There is nothing to prevent making saw cuts as much as 100 feet long and 15 feet deep at a single cutting; but such long cuts are avoided whenever possible because of the likelihood of the sawing strand wearing out or breaking in the course of the operation. The average length of the cuts in the Chapman quarries is about 60 or 65 feet.

As an example of the use of the wire saw, let us assume that there is no back joint in the quarry. A core hole 36 inches in diameter is bored with an Ingersoll-Rand "Calyx" drill to the depth of the proposed blast—say, 14 feet, the wire saw is then installed, and a cut made to the bottom of the hole and at slightly more than a right angle to the grain. We will further assume that the length of the proposed blast is 60 feet and that the other end of the block is free. "Jackhamer" holes are now drilled at the bottom of the mass to be blasted. Their course is along the cleavage, which, in this quarry, dips or slopes from north to south at an angle of about 20° from the horizontal. These holes are loaded with very light charges of black powder and are fired to "raise the split." Down holes are next drilled parallel with the grain and perpendicular to the cleavage or split. These are spaced from 10 to 15 feet apart and are carried to the depth of the blast, which is usually the same as the width of the block to be taken out. This line of holes is loaded to the top with black powder, and all are fired together. This serves to move the whole mass, which measures 14x14x60 feet, from 6 inches to 2 feet.

The mass is then reduced to blocks of hoisting size by means of wedges and feathers. These blocks, at times, reach a maximum of 30x4x1 foot and weigh up to 8 or 10 tons. After being hoisted to the surface by means of heavy cableways, they are placed on tram cars and delivered to the mill by a gasoline locomotive. There they are unloaded by traveling cranes and, if the ends are poor or contain beds of unworkable material, are shaped by a 60-inch diamond saw. This is a circular disk of thin steel having projecting lugs into the outer faces of which are set black diamonds.

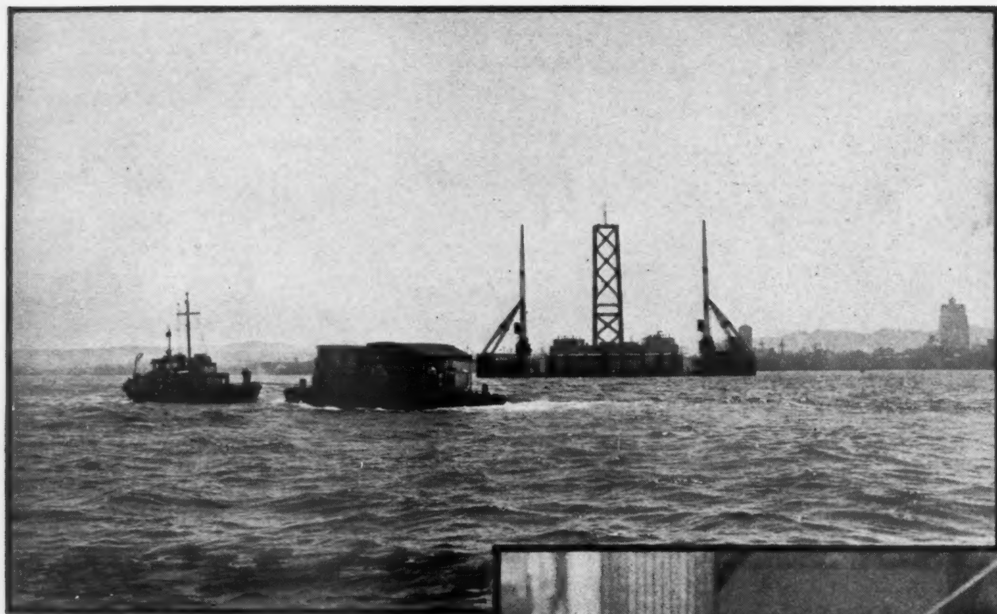
The blocks are now delivered to the slatemakers and "sculped" or cut to desired widths. This is a very interesting operation. A gouge is made in the end of the block, and then the cut or "sculp" is started with a chisel and hammer. By the shape of the gouge and manipulation of the chisel, a skilled workman can control within an inch or two the direction of a cut through a block 15 to 20 feet long.

Having been reduced to suitable widths, the block is next split through its center along a cleavage plane. Thus a 12-inch slab is split into two 6-inch slabs, and these are again subdivided. Finally, the splitter reduces these pieces to standard roofing-slate thickness—3/16 inch. An experienced man does this work with remarkable speed and accuracy, and, without the aid of measuring instruments, produces roofing slate of uniform thickness.

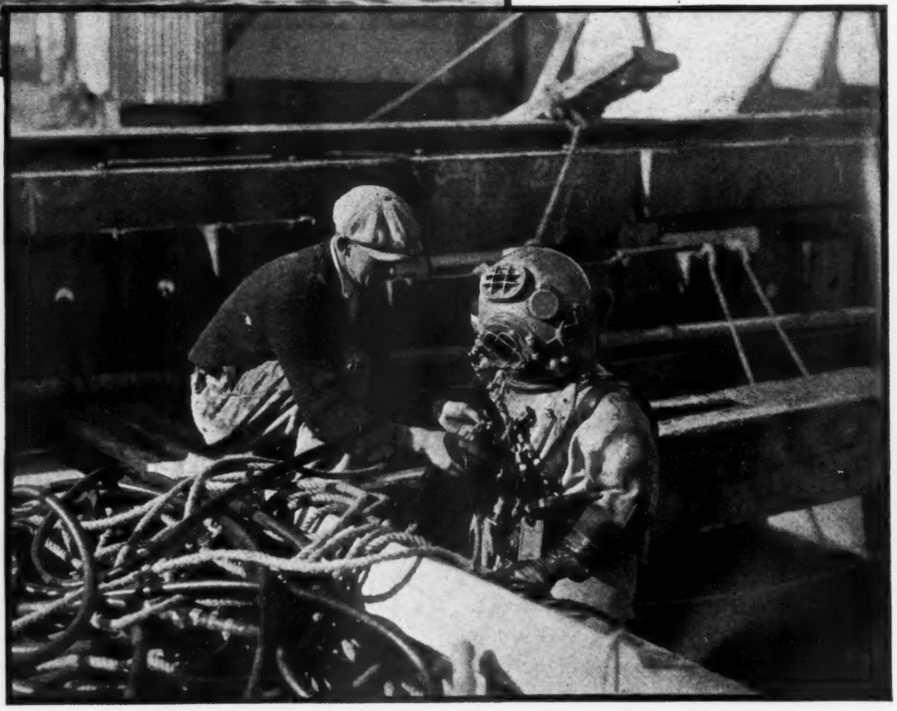
After the splitting operation the pieces are trimmed on a dressing machine to commercial sizes of the required widths and lengths. As they are made, the pieces are placed in the rack of a tram car which, when filled, is hauled to the storage bank. There the slabs are piled on edge, each pile being made up of slates of the same size and thickness.

Roofing slate represents the volume product upon which the industry must depend in the future for its expansion, and practically all slate from the Chapman quarries is used for roofing because it is of the high quality that is desired for that purpose. Chapman hard-vein slate is reputed to be stronger, tougher, less absorbent, and more unfading than any other slate produced in Pennsylvania. The fine, close-grained rock is striated with hard veins of slightly deeper color and of high siliceous content which impart a sheen and texture to the roof. There are no soft carboniferous ribbons that will disintegrate upon exposure to the atmosphere.

As for color, this slate can be best described as being storm blue-gray. In certain lights it bears the hue of the sky as reflected by a still, deep pool or river; in other lights it is of the deep dark blue-gray of an approaching thunder storm; but always it blends perfectly with nature.



DIVING PARAPHERNALIA
The picture below and the one opposite show a diver who works inside a sheet-pile cofferdam erected by Bridge Builders, Inc. for the construction of one of the piers for the new Transbay Bridge



A DIVING EXPEDITION
The tugboat *Active* towing a barge carrying a portable compressor and a recompression chamber for use in treating divers afflicted with "bends" or compressed-air illness. The *Active* is maintained by the State of California for submarine inspection work and is completely equipped for diving operations.

Ancient Art of Diving

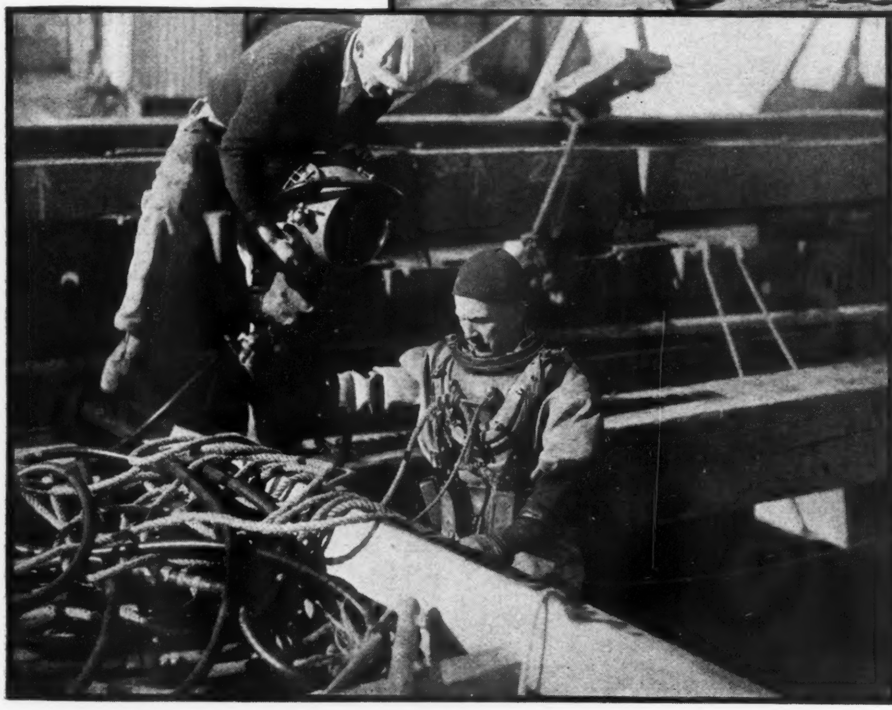
THE human brain has devised ways of conquering many natural forces, but descents into deep water are still largely subject to physical limitations. The hardest granite can be removed so man can walk around freely in openings thus made. Gas-inflated balloons, not to mention the more recent forms of aircraft, will carry people thousands of feet into the air where, until a relatively great height is reached, they can remain indefinitely without undergoing bodily suffering. The penetration of water offers a different sort of problem, however, and no satisfactory means have yet been developed that will permit men to go far beneath the surface, for which purpose they must be incased in structures which separate them from the water, itself, and thereby prevent personal contact with external objects. A fortune greater than any person has ever owned lies strewn about the ocean floor where treasure-laden vessels rest, but most of it is out of reach. Submarines or bathyspheres may get down to some of it, but they are helpless when it comes to retrieving it. Thus far, at least, no mechanical robot has been invented that can enter a sunken hulk and carry out its valuable contents. Only men can do that, and they can withstand pressures only up to a certain point.

At shallower depths, however, human beings can be quite efficient, thanks to the modern diving suit. Breathing air supplied them from the surface at pressures sufficient to offset the hydrostatic head, they can remain for comparatively extended periods, move about, and use their hands. Indeed, much important submarine engineering and construction work at depths of from 30 to 60 feet now depends largely upon divers for its guidance, and their field of service is being extended continually.

Diving for useful purposes has been practiced longer than most people are aware of. In Homer's *Iliad*, which was written nearly 3,000 years ago, reference is made to oyster divers. At the Siege of Syracuse and, again, when Alexander the Great was attacking Tyre, divers were employed to cut harbor defenses that had been placed there to obstruct the approach of enemy ships. In ancient times the inhabitants of the Island of Rhodes, in the Mediterranean, salvaged the treasures of sunken vessels with the help of divers, who were paid a certain proportion of the values recovered.

All these examples concern diving without the assistance of mechanical apparatus. Throughout the Middle Ages various attempts were made to devise appliances that would permit men to work underwater, but none of them was successful. The first material aid did not appear until 1679, when Borelli invented a diving suit that was supplied with air compressed with bellows. From then on steady improvement has been made in apparatus. Modern diving dress is the outcome of an invention by Augustus Siebe in 1819, and with it useful work has been performed at depths of more than 200 feet where the

between San Francisco and Oakland. The one at the left illustrates the air hose being made fast to the diver's suit at a point where he can easily reach the control. Note the weights suspended on straps from the shoulders.



ABOUT TO GO UNDER

A diver about to go underwater in the harbor of a French port. The development of light-weight, thoroughly reliable air compressors like the one shown here has done much to make it possible to conduct such operations from small boats which can move quickly to working locations.

Aids Underwater Work

pressure exceeds 100 pounds per square inch. There are a few cases on record of exceptional depths reached by divers in the conventional dress—that, for example, of 306 feet in salvaging the U. S. Submarine *F-4* off Honolulu.

Recently, in examining the foundation for one of the San Francisco-Oakland Bay Bridge piers, William Reed descended 242 feet. Mr. Reed was one of the salvors of U. S. Submarine *S-51* which sank off Block Island in September of 1925 after being rammed by the *City of Rome*. He added to his laurels as one of the nation's foremost divers during the war. He was aboard the hospital ship *Graf Waldersee* when it was damaged below the water line in a collision with a freighter. Donning his diving suit, he was lowered to the point where the hull was punctured and spent considerable time there during three days and nights placing patches. The ship was returning from Europe with wounded soldiers. Mr. Reed is now California State Submarine Inspector and maintains a motor boat which is especially equipped for deep diving. This craft tows a barge on which is mounted a decompression chamber for the emergency treatment of any diver who may become afflicted with "bends."

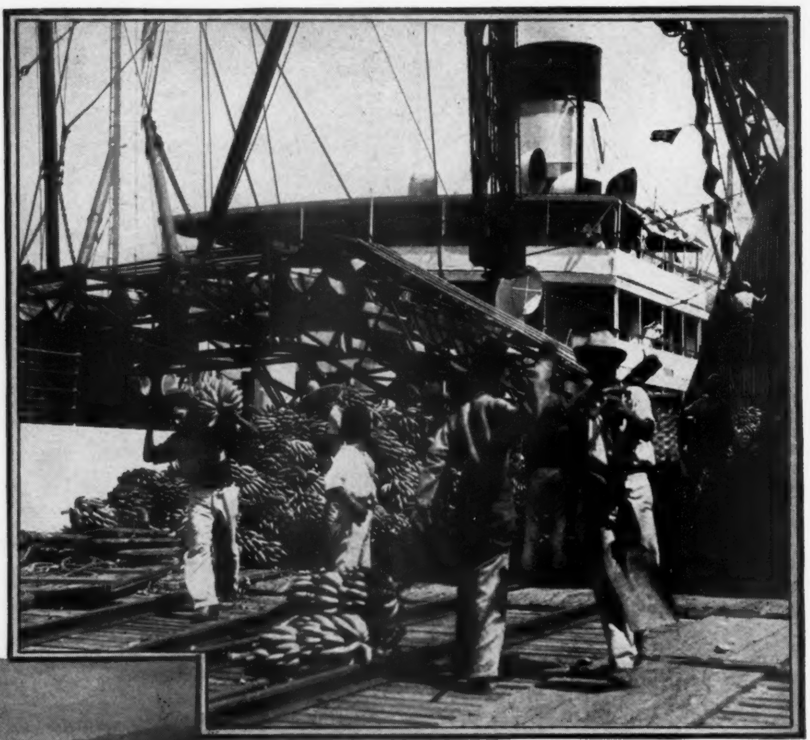
Obviously, one of the vital requirements of a diver is an unfailing supply of fresh air, and the development of reliable compressors has filled this need. Formerly the air was pumped below with manually operated apparatus. When steam- and motor-driven compressors became available, they were used for operations close to shore; but where diving was conducted from small, open boats, there was no room for such machines and hand-operated pumps continued to be employed. It was not until of late years, with the advent of light, compact, and thoroughly dependable gasoline-engine-driven compressors, that air-producing apparatus has been provided suitable for this isolated service. These units are similar to those utilized in laundries, and they also have various industrial applications where the demand for compressed air is light. It is no small tribute to their manufacturers that they are so certain in their operation that diving concerns unhesitatingly place full reliance upon them and do not equip their boats with reserve machines.

One of these compressors is shown in an accompanying illustration. It is an Ingersoll-Rand Type 30 unit with one air-cooled compressing cylinder and the entire assembly resting on a receiver of adequate capacity. Three machines of similar type are used in connection with the placing of underwater structures for the new Transbay Bridge. In order that the air sent to the divers shall be free from contamination, it is essential that not more than a trace of lubricating oil should be carried over from the cylinders. Such compressors ordinarily discharge at a pressure of 80 pounds to the square inch. The pressure is reduced to meet the requirements of the diver, and depends upon the depth at which he is at work.

Silver and Gold from the Spanish Main

Honduras Region that Has Been Mined for Centuries Still Yields Precious Metals

J. J. GRAY



LOADING BANANAS

By virtue of the bananas that are grown and shipped by the United Fruit Company and the Standard Fruit Company, Honduras enjoys excellent steamship service with the United States. Bananas are the leading export of the nation. The loading scene shown above was photographed at La Ceiba, on the north coast.

MACHINE SHOPS AND MILL

The Rosario property is self-sufficient, as befits its isolation. Ore is milled and the concentrates made into bullion on the ground. The mill is at the upper left and just above are the machine shops, which are equipped to perform all operations that are ordinarily required.

ON HIS fourth and last great voyage of exploration, Christopher Columbus, in 1502, set foot for the first time upon continental America. For several weeks his vessels sailed along the shore unable to find anchorage in the deep water. Finally, they rounded a projection and found beyond it a small, sheltered harbor. In token of his gratitude at finding this haven, Columbus named the promontory Cape Gracias a Dios—Cape "Thanks to God." He called the country on which he landed Honduras. This can be translated either as "depths" or "wavelike" and it is assumed that it refers both to the deep coastal waters and to the succession of mountain ranges rising one above another on the mainland.

Columbus learned from natives that there was much gold in this new land, and it was his intention to plant a colony there and to make it his home. This plan fell through, however, when some of his men became involved in a quarrel with the natives; and after a few weeks Columbus withdrew never to return. Twenty-two years later, Hernando Cortez, engaged in wresting Mexico from the great emperor Montezuma, heard that there was a country rich in mineral to the south, and he sent one of his lieutenants, Christobal de Olid, to take possession of it in the name of the Spanish crown. De Olid found Honduras so much to his liking that he determined to keep it for his own. Tidings of this defection reached Cortez in the following year, 1525, and he immediately began a long march over the mountains. Arriving at the colony, he founded the City of Puerto Cortez, set up a government with one of his trusted men in charge, and returned to Mexico to resume his conquest of that country.

The Honduran mines soon proved themselves to be the richest in the New World, and for several centuries thereafter a steady stream of wealth flowed from them to Spain. During the eighteenth century they poured forth their riches in enormous

amounts. As it seems certain that the natives had extracted gold from the stream-beds long before the coming of the Spaniards, the total yield of precious metals from this region must have been fabulous.

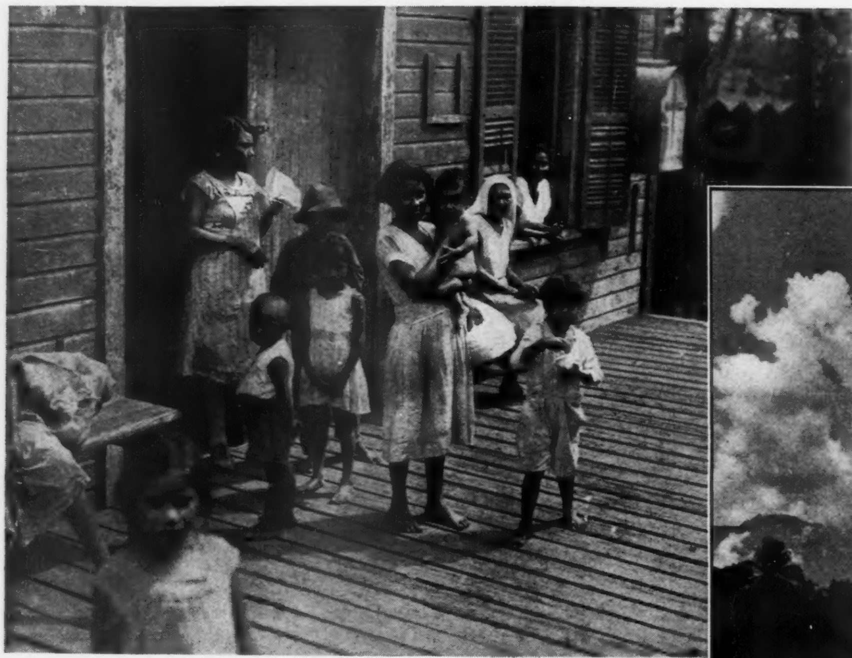
Although greatly depleted by untold years of working, the deposits still support a few profitable mines. Outstanding among these is the New York & Honduras Rosario Mining Company, a United States concern. It is chiefly a silver producer, although appreciable amounts of gold also are mined. This company has been carrying on for 54 years, maintaining operations in the face of political upheavals, wars, and other handicaps. During that period it has produced nearly $50,000,000 in silver and gold and has paid out to its stockholders dividends of more than $10,000,000. Its property is located about twenty miles from Tegucigalpa in the same general region, which has accounted for a considerable portion of the past output. Tegucigalpa, a city of 40,000 persons, is situated in the mountains at an elevation of 3,200 feet, and bears the distinction of being the only capital city in the Americas which is not served by a railroad. Tegucigalpa is 84 miles by road from San Lorenzo, which is on the southern or Pacific Coast. Because of the shallowness of the Gulf of Fonseca, however, vessels cannot put in at San Lorenzo. All cargo is unloaded at the Island of Amapala, twenty miles offshore, and lightered from that point. Transportation inland is still rather primitive, and, until recently, supplies for the mine were moved from the coast either by muleback or by bull team, depending upon the size of the pieces carried. The journey required seven days by mule or fifteen days by bull team, and the cost of freighting was $35 per ton by the former method and $45 by the latter.

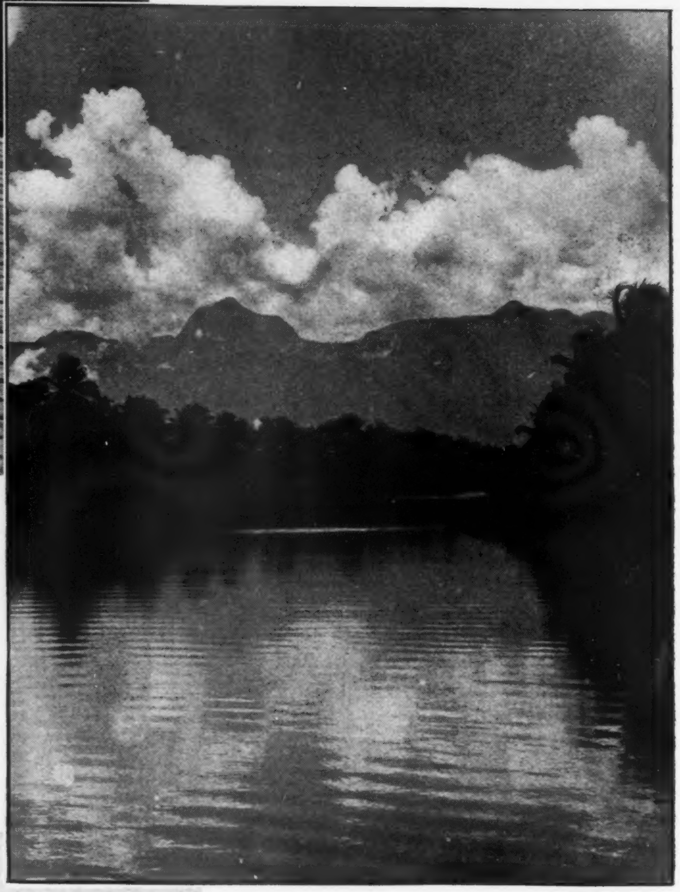
Honduras has an area of 44,275 square miles, or a little more than that of the State of Kentucky. Its population is less than 900,000, with Indians predominating. Some of the natives, variously estimated at from 50,000 to 200,000, still live much as their forbears did for centuries, keeping to the remote mountainous sections. In the cities, persons of mingled blood are found; and as is usually the case in Latin America, most government offices are held by persons who can lay claim to Spanish ancestry.

Honduras depends for revenue chiefly upon her exports of natural products. In bygone years metals held a leading position, but this is no longer true. Bananas now occupy first place. They are cultivated and exported by the United Fruit Company and by the Standard Fruit Company, and by virtue of this traffic Honduras enjoys excellent steamship service to and from the United States. Other important products are mahogany and other tropical woods, sugar, coffee, and cattle. The country owes most of its railroad system to the development of various natural resources by foreign concessionnaires. The national railroad line is only about 60 miles long, which is approximately one-tenth the length of privately constructed systems. Most of the country's foreign commerce is carried on with the United States.

The Nicaraguan Cordillera extends across the southern part of Honduras. This is a range of igneous rocks in which are numerous volcanic peaks. Between it and the Pacific Coast is another and a lower range which was, it is believed, uplifted after the formation of the main chain. The principal

HONDURAN TRANSPORTATION
Mules and oxen still constitute the backbone of the carrier system, or, perhaps, it would be more literal to say that the backbones of mules and oxen bear most of the burden of transportation. The top picture shows bars of bullion loaded for shipment, and the bottom one depicts the arrival of a supply train at the mine. An ox-drawn freight expedition is shown in the center just as it reached the coast after a 100-mile trip.





NATIVE SCENES

With its elevation varying from sea level to 11,000 feet within a span of 100 miles, Honduras has a picturesque scenery. In the mountainous sections the climate is equable, and the heat is never oppressive. Heavy rains are confined to one-half of the year. Numerous streams, some of them navigable in their lower reaches, flow from the highlands to the two coasts. To the right is a view of the Salada River. The population is heterogeneous, but native Indians still make up its greater part. The family group above was photographed at La Ceiba.

areas of mineral production are in the higher mountains. Climatic conditions, on the whole, are favorable to comfort and health. At the Rosario Mine the annual temperature range is from 45° to 80°F., with an average of 65°. There are only two seasons, wet and dry, with most of the rain falling between May and January.

The New York & Honduras Rosario Mining Company was incorporated in New York in November, 1880, and began operations soon afterward. It owns about 30 square miles of land in the section which is now being worked, and also controls the San Marcos Mine of the Sabana Grande Company some 40 miles away. The Rosario Mine is approximately three miles from the Town of San Juancito; and so far more than twenty veins of workable size and richness have been found. These lie in a formation consisting of slate, andesite, rhyolite, and altered granite. They are distributed throughout a mountain which rises to a height of more than 7,000 feet. Twenty levels, disposed at vertical intervals averaging 125 feet and connected by chutes, have been cut in developing the property, and the workings aggregate several hundred miles in length. At the lowermost level is a horizontal haulage tunnel through which the ore is transported out of the side of the mountain to the mill. Owing to the method of mining followed, no pumping of water is required.

STUCK IN THE MUD

During the rainy season horses occasionally become bogged down. Sometimes they have to be literally pulled out.

This mine is noteworthy because it is the only completely mechanized mineral producer in Central America. Hydro-electric plants were constructed on a nearby stream more than 25 years ago, making it possible to operate all machinery in the mine, mill, and accessory structures with electric power. One of the corollary effects of this has been to permit the use of electric-driven compressors; and the abundant supply of compressed air has added greatly to the over-all working efficiency of the property.

Initially, the company did all mining by hand drilling. After a few years it installed a Rand 500-cfm. compressor driven by a water wheel, and this was considered such a marvelous machine in that country that the president of the republic traveled over the mountains to inaugurate the service. The air delivered by this unit was used to operate old-style piston drills. In 1908, when electric power became available, two compressors, direct driven by induction motors, were secured. These machines, which are of the Ingersoll-Rand PRE type, are still in regular service after 25 years. In 1924 a third unit of a similar type but with a synchronous motor was installed, giving

the mine an air supply of approximately 5,000 cfm. This air is transmitted into the mine workings through a 10-inch pipe line which is 3,300 feet long. Somewhere around 95 stoping drills and 35 drifters are operated in addition to a number of "Jackhamers", air hoists, and other pneumatic equipment. Three other compressors, having a combined output of about 2,000 cfm., furnish air for use in the machine shops and in the mill, thus making available at the property a total air supply of approximately 7,000 cfm.

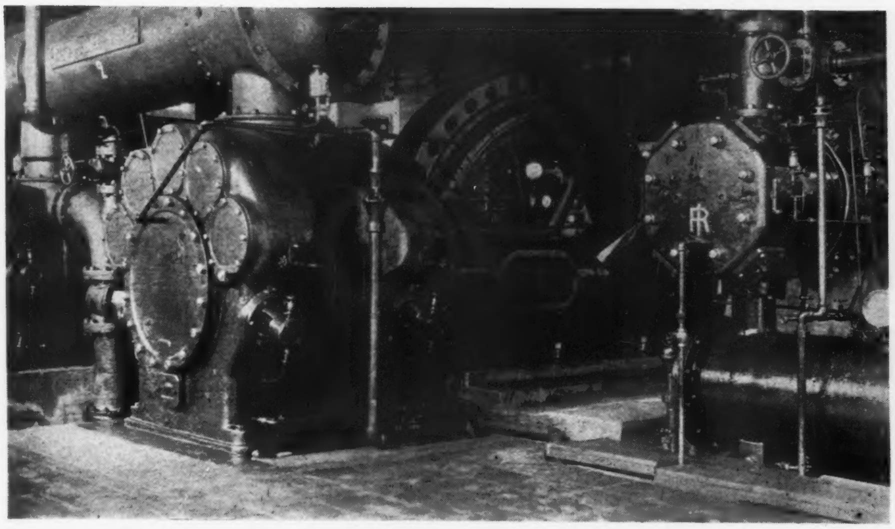
Save for about 40 foreigners, mostly Americans, all the work is done by natives, of which around 550 are in the mine alone. As no other mine in Central America is worked with machinery, as already mentioned, all these men have had to be trained on the job. They have proved themselves adept, however, and have become efficient at running rock drills or performing other operations within a short time.

Ore and waste are hauled by electric locomotives, of which 5-, 6-, and 7-ton units are in service. As many of the working points are two miles or more from the portal of the haulage tunnel, the daily transportation of several hundred tons of material by any other means would constitute an almost impossible task.

Most of the silver occurs in the mineral stephanite, a silver-antimony sulphide. A small amount of free silver is found. The ore is amenable to treatment by cyanidation and zinc-dust precipitation, and a mill embodying that process handles the entire output. This plant is equipped with twenty 1,850-pound stamps and ball and pebble mills, and is constructed upon a steep sidehill which facilitates its gravity-flow design. The product of the mill is made into bullion on the property.

Production in 1933 was the highest in the history of the company, and profits likewise exceeded all past records. Primarily responsible for this was the increased price of gold, for any rise in the return from this metal, even though it is a by-product, consequently reduces the cost of recovering silver. During that year there were mined and milled 147,100 tons of ore having an average content of 29.077 ounces of silver and 0.1241 ounces of gold per ton. Silver recovery amounted to 91.45 per cent, aggregating 3,911, 686 ounces having a value of $1,428,707.58, while that of gold was 94.27 per cent or 17,210.63 ounces worth $482,032.59. The combined value of the gold and silver was $1,910,740.17; and the net profit for the year, including $101,-183.14 from investments, was $759,197.21 after all deductions.

The company has always pursued the policy of doing sufficient development work each year to keep a fairly constant reserve supply of ore ahead of operations. At the beginning of 1934, the reserves which could be profitably mined at current prices of gold and silver amounted to 468,087 tons, and of this 33,387 tons was broken in stopes and ready for extraction. In addition, there were 48,000 tons of ore listed as inactive reserves by reason of the fact that their content of recoverable metal was not large enough to yield a profit at prevailing market prices. In developing existing ore bodies and searching for new ones, 25,573 feet of openings were driven during the year, consisting of 12,620 feet of drifts, 6,100 feet of crosscuts, and 6,853 feet of raises. Production during the year all came from nine veins. In a further effort to find new sources of ore, diamond-drilling was initiated in 1932. Eleven holes, all horizontal and ranging from 140 to 600 feet in length, were drilled during 1933. They totaled 4,110 feet, and their average cost was $3.91 a foot.



VETERANS OF ROSARIO SERVICE

These large air compressors have been in use since 1908 and, although their induction-type motors do not possess the advantages of synchronous-type motors now generally employed, the condition of the machines is such that they are considered good for more years of service. There are several other compressors on the property, and the aggregate capacity of the plant is approximately 7,000 cfm.

The three hydro-electric plants are all located on one stream and operate at respective heads of 475,782, and 1,290 feet. Two of these were originally installed a number of years ago and were rebuilt and increased in capacity in 1924 and again in 1926. It was thought that they would suffice for all needs; but in 1930 an unusually dry year was experienced, the rainfall totaling only 34.71 inches as compared with an average of more than 54 inches. Accordingly, a third plant was constructed to augment the power supply during low-water periods. This station is automatically controlled from a distance of about a mile, thereby eliminating an attendant. A steel-tower, 6,600-volt transmission line carries the current about five miles across the mountains to the mine and mill. During 1933 there was used more than 9,000,000 kw-hrs. of power, the consumption being 61.66 kw-hrs. per ton of ore mined and milled. The cost of generation was about 1½ mills per kw-hr. Under a government concession the company built a water line to the cities of Tegucigalpa and Comayagucla.

ALONG THE SALADA

Barges such as this one handle much of the lowland traffic.

Because of the isolated location of the property, the New York & Honduras Rosario Mining Company maintains extensive accommodations for its personnel. Members of the foreign group are provided with electrically lighted and heated quarters, and a hotel supplies meals for the single men. A club building contains billiard and card tables, a library of more than 3,000 books, and other recreational facilities.

The camp includes a modern, completely equipped hospital with a competent medical staff where services and medicine are free to all employees. During 1933 this institution handled 13,339 cases. The company also conducts four schools for the education of the children of both native and foreign workers. These had a combined attendance of 313 during 1933. And, finally, a paid police force of 20 selected men preserves peace and order.

This and That

Why the Cat Came Back

We don't wish anyone to construe the printing of the subjoined material as license to blame the manufacturers of compressors for some of the queer sounds that come over the radio under the guise of entertainment. Due acknowledgment is made to the anonymous conductor of a column on the radio page of the *Cleveland News* who reported the episode in the October 10, 1934, issue of that paper.

When we opened the office door this morning, the place smelled like a gasoline station.

Lying on the chief editorial writer's desk was a small outboard motor and just above it, on top of a pile of old newspapers, lay Charley, the office cat, asleep.

When he heard the door close, he opened one eye.

"Hiya Buck," he yawned. "S'prised to see me?"

"Not especially," we replied, "Wednesday's our unlucky day. Anyway, where've you been?"

"With the Byrd expedition," he said, flicking the ashes from a cheroot he had just lighted. "But I got tired of it and came back. I used this motor."

"How?" we inquired.

"Oh, just hooked it on my tail and zipped right along. I got here in no time."

"But why did you come back?"

"No radio programs," he said, "that is, none worth mentioning."

"Both chains send programs down there each week," we told him.

"Yeah," said Charley, "but when they get through bouncing around the icebergs, they're not worth much. But I did have a peculiar experience down there.

"Evelyn (I always call the commander by his middle name) took along several tanks of compressed air. So one day I'm letting some of the air blow the snow out of my whiskers, and all of a sudden, a Vallee program comes out. Right after that I got the Showboat and the Whiteman hour. Whoever had bottled the air had got it when it was filled with those shows."

"And you expect me to believe that?" I asked.

"Believe it," Charley demanded, taking his motor under his arm and starting for the door, "what do you think I am, a builder-upper?"

And with that he was gone.

* * *

The Toll of Erosion

The TVA has estimated that, unless corrective measures are taken, Norris Dam on the Clinch River will be completely filled with sediment in 100 years. This emphasizes the extent of the erosion in certain parts of the Tennessee Valley. In order completely to control the ravages of erosion, Chairman A. E. Morgan believes that the TVA should acquire jurisdiction over some 10,000,000 acres of land. Obviously, this cannot be done; and while considerable areas will be purchased, yet for the major portion of the curative work it will be necessary to rely upon the coöperation of the present property owners. By those who have studied the basin, it is held that 55 per cent of the land is unsuited for crop cultivation and should be planted with trees or with soil-fixing vegetation.

* * *

Boom Town Prices

In her recently published autobiography, *A Child Went Forth*, Dr. Helen MacKnight Doyle, who was one of the first women to become a physician on the Pacific Coast, includes a copy of a menu from the Eldorado Hotel in Hangtown, a California gold-rush boom city. Prominently displayed on the slip was the cryptic note, "Payable in Advance." Some of the items listed follow: Bean Soup, \$1; Beef, with one potato (fair size), \$1.25; Baked Beans, plain, 75c; Baked Beans, greased, \$1; Two potatoes, medium size, 50c; Two potatoes, peeled, 75c; Hash, low grade, 75c; Hash, 18 carat, \$1; Codfish Balls, a pair, 75c; Rice Pudding, plain, 75c; Rice Pudding, with molasses, \$1; Rice Pudding, with brandied peaches, \$2.

* * *

Canada's Mineral Boom

Government figures show that Canada's mineral production now ranks second to field crops among her industries. For 1933, the value of the Dominion's produce was \$422,148,000, while that of the minerals taken from the ground was \$220,501,000. During the past year agricultural exports have increased 13 per cent and mineral exports have risen 60 per cent. The appreciation in the price of gold has been the most potent factor in the climb of mineral production, and it is predicted that, in 1934, gold alone will account for \$100,000,000 of her new metallic wealth.

In this appraisement of national resources, Canada is discovering that enormous incidental benefits are accruing from her mining activities. The average miner receives \$5 a day and works steadily. In the Province of Ontario, alone, \$21,500,000 was paid to mine employees in 1933. Wages are mostly spent for consumer goods; and retail trade in all mining districts is good. When the camp of Porcupine had only twelve miles of roads, there were 200 automobiles there. Aside from payrolls, the mines expend huge sums for plants, permanent equipment, and current supplies, all of which aids the manufacturing and transportation industries. Still more money is placed in circulation through the payment of dividends on stocks.

Vibrations from Blasting

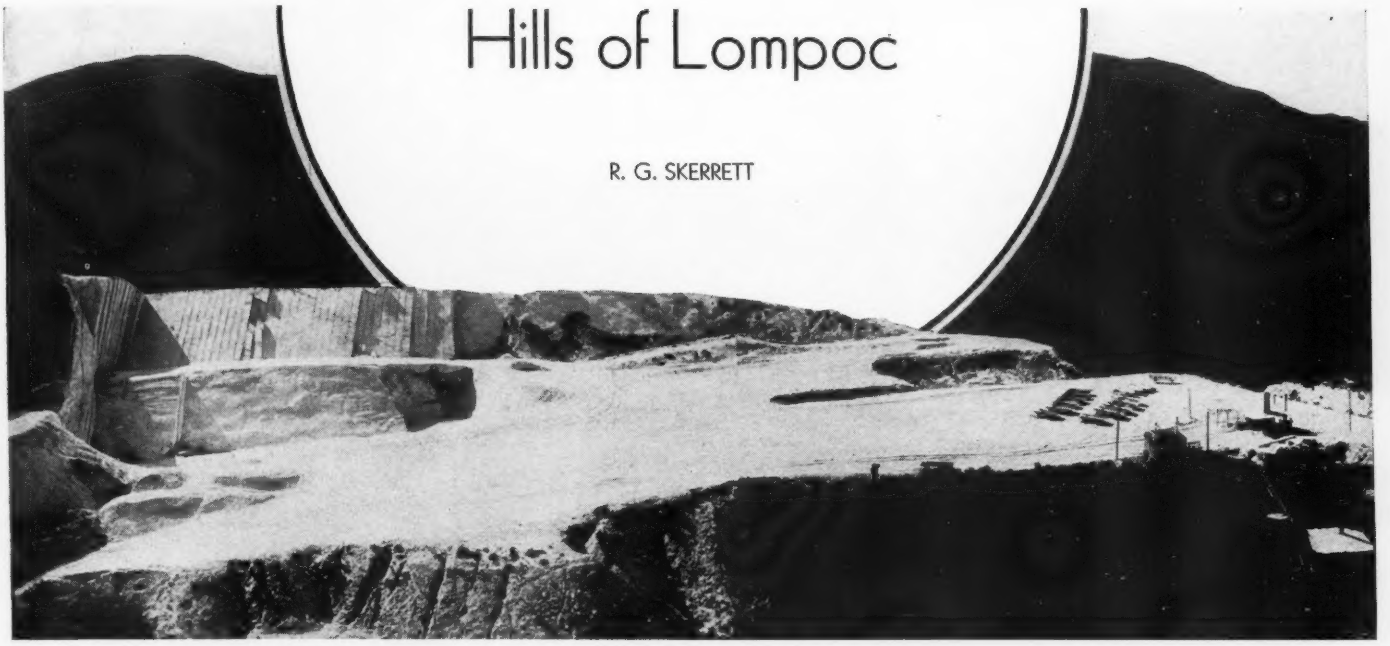
In our October issue was a brief description and illustration of what are known as vibration pins, which were used by a road contractor to check the effects of blasts upon a nearby power house. There has now come to our attention an interesting pamphlet by Prof. Edward H. Rockwell, of Lafayette College, that goes into this general subject in a thorough manner. The paper is entitled, *Vibrations Caused by Blasting and Their Effect on Structures*, and is distributed by the Hercules Powder Company. The author attributes the first use of vibration pins to the General Crushed Stone Company, which employed them in 1920 to determine whether buildings in the vicinity of quarries were being damaged by shots.

Professor Rockwell's discussion reveals that the effect of blasting is generally overestimated. He cites as an illustration the case of a young man who conscientiously declared that his dining-room floor moved up and down more than 2 inches during a blast of 1,000 pounds of dynamite more than 2,000 feet distant. When a vibrograph was set up, and the blast repeated, it was proved that the floor actually moved less than one one-hundredth of an inch. The vibrograph is a small, portable instrument that is built on the same fundamental, scientific principle as the seismograph. The author brings out the point that the vibrations usually are more likely to cause damage in alluvial soil than in rock. Rock acts more like an elastic solid and recovers its original position, while soil is displaced.

Damage to buildings from blasts ordinarily shows first in the plaster, since that is the weakest material employed in building construction. The tendency is to ascribe these cracks to some outside influence, whereas, Professor Rockwell states, natural causes such as shrinkage, temperature, contraction, or settlement are generally to blame. Fortunately for those whose blasting operations may be held responsible, the nature of the cracks is evidence of their cause. Contraction cracks occur as horizontal or vertical lines parallel to structural units such as beams or columns. Cracks arising from settlement or from the bending of beams assume diagonal directions. Vibration cracks invariably cross each other at right angles, a characteristic which is explained by the fact that they are brought about by alternating stresses of opposite kinds. Such cracks are commonly seen in earthquake areas. Although Professor Rockwell conducted nearly 100 experiments with blasts, in no case was the resultant vibration heavy enough to produce these crisscross cracks.

Hills of Lompoc

R. G. SKERRETT



STUDY IN BLACK AND WHITE

The shimmering whiteness of the exposed deposits of diatomaceous earth serves, by contrast, to make the surrounding hills seem black. This picture shows how the chalk-like substance is sawed into sections to permit its removal for drying and subsequent treatment without destroying its intricate structure.

Source of Diatomaceous Earth, a Material that Has Many Uses

IN SUNNY Santa Barbara County, California, there is a cluster of hills, about ten miles in from the sea, that appears to be continually covered with snow. Of course, in that land of oranges and year-round flowers, those shimmering hills are not really cloaked with snow. Their deceptive appearance comes from the blanched substance that forms their masses— that is, the compacted fossil skeletons of countless trillions of diatoms which were deposited there during a past geological epoch.

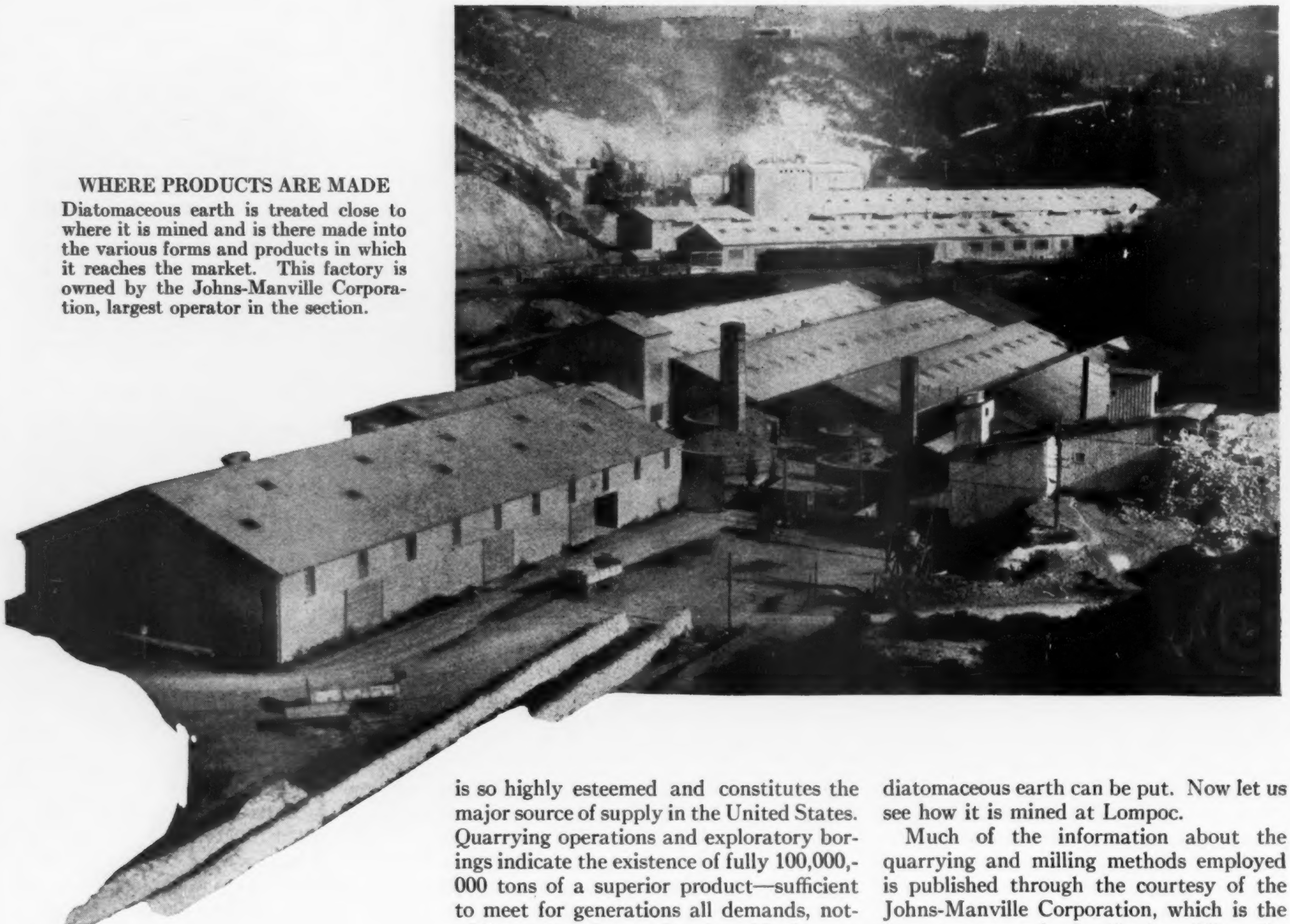
The region is close to the Town of Lompoc, and just north of the Sierra Santa Ynez range. The altitude varies between 500 and 1,800 feet above sea level. Diatoms in the past, as diatoms of today, were minute forms of plant life found in salt and fresh waters. Diatoms, as their name indicates, split into two parts during the process of reproduction. In the course of a month, so it is said, a single frustule, through successive subdivisions of its kind, can become the source of fully a billion diatoms. Diatoms, for untold ages, have been the primary source of food of many aquatic creatures and, indirectly, a source of sustenance for the larger denizens of the deep that feed upon the smaller ones.

As Dr. Albert Mann has explained: "In the sea, as on the land, animal life is dependent upon plant life for the transformation of the inorganic substances of the earth into organic materials that shall serve as food. . . . . Carbon, oxygen, hydrogen, nitrogen, phosphorus, potash, etc., will not juggle themselves into edible compounds. It is only by the alchemy of the green, chlorophyl-bearing plants that these combinations are brought about. The diatom is the smallest of all the green, chlorophyl-bearing plants." Nevertheless, these extremely minute organisms, because of their numbers and their tireless activities when alive, are capable of working wonders in the way of vital transformations. For this reason diatoms have been called "the grass of the sea." It is a scientifically established fact that individual species of diatoms retain their distinctive characteristics through many thousands of years; and the fossil remains in the Lompoc beds are identical with diatoms now existing in the Arctic Ocean.

The fossil diatoms in the deposits at Lompoc were laid down during the Miocene period—probably two million years ago; and as these microscopic organisms died and settled to the water bed they gradually built up a layer more than 1,400 feet in thickness. How long this process continued cannot be determined, but it must have gone on for ages because a cubic foot of the diatomaceous earth holds entombed as many as 40,000,000,000 skeletons of these prehistoric plants. When viewed through a microscope capable of enlarging them to about 500 diameters, these wee organisms amaze the beholder because of their intricate and marvelous beauty. Their exquisite structures surpass anything that man can do in the symmetrical arrangement of lines and curves. No wonder these geometrical gems have been termed "jewels of the sea." Paradoxically, it is the elegance of these tiny but complicated siliceous structures that makes them of present value to man in numerous practical ways.

How did the diatoms—undoubtedly of Arctic origin—reach their final resting place close to the coast of California as it is today? Diatoms are of numerous varieties, but those that reached the area about Lompoc had skeletal forms that were wide and thin or long and narrow—the dimensions being on a lilliputian scale; and when the organisms were alive they presented a maximum surface to the water and had a minimum tendency to sink. In other words, their modeling was suitable for an extended voyage. These buoyant bits of plant life were picked up by some ocean current and swept along until they reached a point far down the coast. At that time, the land upon which Lompoc stands today was part of the sea bed. What, then, arrested the diatoms in their involuntary journeying?

In all probability, a projecting bar or perhaps a peninsula stood athwart the path of the remote Arctic stream and caused at least some of that cold current to turn inland where it circled in a leisurely fashion within an existing bay. The diatoms, so detoured, followed their ordered cycle of life—a period that may have been shortened by changes in the temperature and the salinity of the sheltered water. The diatoms, as they died, sank to the bottom; and live ones, drifting continually



WHERE PRODUCTS ARE MADE
Diatomaceous earth is treated close to where it is mined and is there made into the various forms and products in which it reaches the market. This factory is owned by the Johns-Manville Corporation, largest operator in the section.

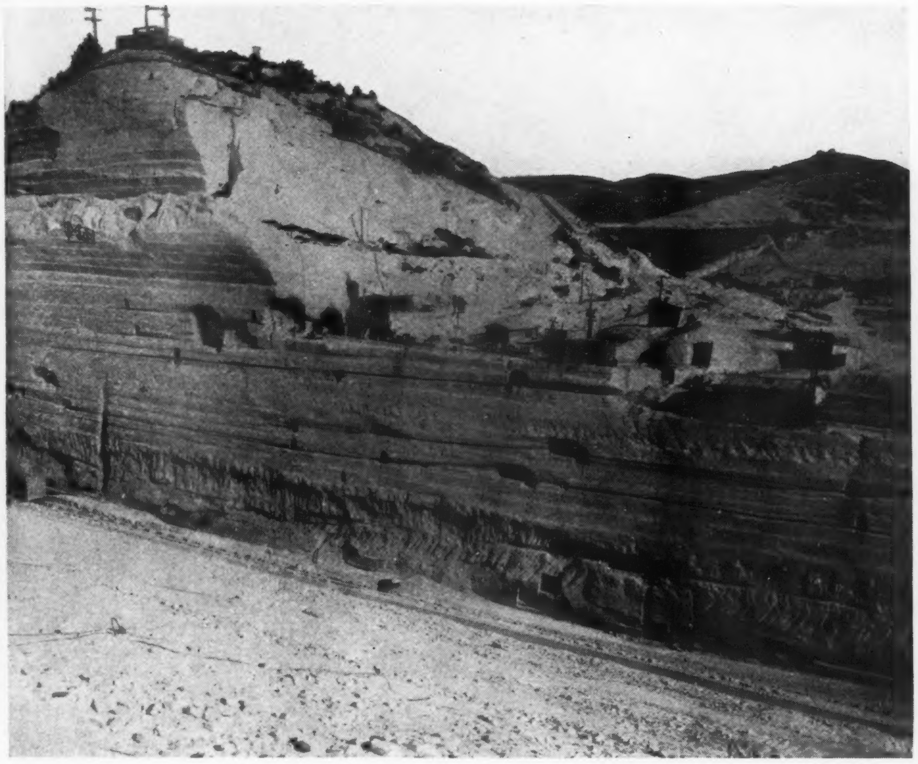
from the north, maintained a supply until some crustal disturbance closed the gateway to the sea. The movement that uplifted the whole coast brought this about, but the path to the sea may have been opened and shut a number of times before there was formed the land-locked lake in which the diatoms eventually ceased to propagate. Incidentally, the sun finally dried up the lake. Within the Lompoc beds, which cover an area of about twelve square miles, fossil remnants of fishes of different sizes and kinds, and parts of a mammoth and a whale have been uncovered. A layer about 500 feet below the top of the deposit carries the fossilized bones of herrings, many of them carbonized and indicating that the fish were destroyed well-nigh instantly. The catastrophe must have occurred long before the diatoms ceased to upbuild the bed that now holds the last reminders of them, and also before the sea bed was folded upward to form the hills of Lompoc.

One thing is reasonably certain: turbulent and muddy waters almost never flowed into the prehistoric bay, for the deposits are remarkably pure, and such layers of clay, or other sedimentary matter, as are interposed are very thin and relatively far apart. This is one reason why diatomaceous earth from the Lompoc deposits is so highly esteemed and constitutes the major source of supply in the United States. Quarrying operations and exploratory borings indicate the existence of fully 100,000,000 tons of a superior product—sufficient to meet for generations all demands, notwithstanding the continually widening applications of this unique substance of nature's making.

Diatomite, as it is commonly called, is useful because of its distinctive characteristics. These are: extreme fineness and uniformity, light weight, and high porosity. Furthermore, because the structure is of silica, the minute skeletons resist the action of acids and most solvents, and thus retain their cellular formations where others would be broken down. When dry, a cubic foot of diatomite weighs between 18 and 20 pounds, and is capable of absorbing from 1½ to 2 times its weight of water. While utilized for many purposes, diatomite is preëminently valuable as a filtering and clarifying agent, as a thermal insulator, as an absorbent, and as a filler in numerous commodities. It is also employed as a mild abrasive for polishing metals, glass, furniture, and enamel; and some tooth pastes and some nail polishes contain it. Its virtue as a finishing medium is owing not only to the fineness and uniformity of the microscopic granules of siliceous matter but also to its porous structure and low compressive strength, which causes it to crumble under pressure and to act as an abrasive without scratching. Diatomite is a good cleanser because, in addition to its mild abrasive action, it readily absorbs grease, coloring matter, and other impurities. So much by way of a mere outline of the uses to which diatomaceous earth can be put. Now let us see how it is mined at Lompoc.

Much of the information about the quarrying and milling methods employed is published through the courtesy of the Johns-Manville Corporation, which is the largest operator in the district. When the soil overburden has been removed and the underlying diatomite has been bared, then a special form of chain-saw channeling machine traverses the quarry floor and scores the chalk-like substance with kerfs about 4 feet deep and spaced so as to divide the surface into 4-foot squares. The cubes or columns thus isolated are still bound to the formation at their bottoms. Hand picks, pneumatic paving breakers, and air-driven clay diggers are variously used to break them free along the natural bedding planes. The cubes are also successively split horizontally into sheets or layers 7 inches thick, which, in turn, are fractured into smaller lumps that can be readily handled preparatory to drying. The quarry practices are in a state of flux, because there is an unfailing effort to improve production and to reduce losses—especially those arising from the tendency of the earth to crumble into dust and to be broadcast by the winds.

Much of the diatomite is stacked in the fields for drying; and the slabs so treated average 7 inches in thickness and from 1½ to 2 feet across on the face. They are arranged in a series of parallel piles—each about 5 feet high and 500 feet long, and with room for driveways between the rows. After an exposure to the sun and the wind for a month or two, the moisture content is reduced to less than 10 per cent. When



OPEN-CUT WORKINGS

The deposits near Lompoc cover about 12 square miles, range in thickness to 1,400 feet, and contain an estimated 100 million tons of high-grade diatomaceous earth. Although most of the mining is done in open pits, there are some underground operations, and tunnels have been driven to provide haulageways between adjoining workings.

MAGNIFIED DIATOMS

Photomicrograph of diatomaceous earth, showing individual organisms. There are as many as 40 billion diatoms in a cubic foot of earth, yet the microscope reveals that each has a distinctive and finely knit structure.

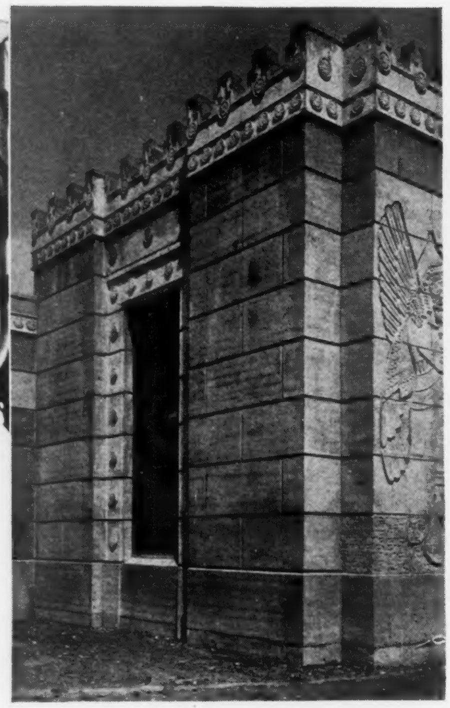
first quarried, the earth may carry up to 45 per cent moisture; but when in a salable condition, moisture must not exceed 8 per cent. While breakage in stacking and subsequent transfer to the mill is considerable, and much marketable diatomite is swept away by the wind, open-air drying still is more economical than would be the burning of oil or coal to effect evaporation. The amount of water to be disposed of should make this plain.

Once the diatomaceous earth is sufficiently dry, it is moved to the mill, and from that point onward it is very largely handled pneumatically. At least, such is the case with the granular and pulverized diatomite. The primary purpose in milling diatomite is to disintegrate it only to that degree which will separate the individual fossils—compacted during the formation of the beds—without crushing the minute cellular structures and impairing their effectiveness as filtering mediums and insulating agencies. Therefore, it is milled so as to avoid destructive pulverizing. After milling, the diatomite is blown through a series of collectors fitted with screens that range successively from 100 to 250 meshes to the square inch. The very fine dust that issues from the last of the collectors is caught in cloth bags. This is particularly useful as an ingredient in polishing preparations such as those employed on lacquered automobiles. It is also utilized as a filler in the manufacture of talking-machine disks; and of late years diatomite has served to an increasing extent as a filler in the making of battery boxes. For this purpose the material has to be low in acid-soluble substances, iron, manganese, and other foreign matter.

A granular form of diatomite, composed of from 5-mesh to 20-mesh particles, with some dust, is widely used for filling between walls and over ceilings for thermal insulation. It is said that a 4-inch layer of the material has an insulating value equivalent to that of a brick wall from 30 to 40 inches thick. Lompoc diatomite is nearly 90 per cent silica, and this and the innumerable minute cells of each tiny diatom make it effective as an insulator at high temperatures. The products of the Johns-Manville Corporation are essentially of four classes: pulverized and granular diatomite, calcined granular diatomite, bricks cut directly from untreated diatomite, and calcined bricks made from somewhat coarsely powdered diatomite. Both powdered and granular diatomite, mixed with a suitable binder, form a plastic insulator fit for many purposes in connection with boilers, glass furnaces, lime kilns, etc., and are durable and effective for temperatures ranging from 1600 to 2000°F. Three kinds of bricks are manufactured. The one that is cut directly from selected strata of diatomaceous earth can be subjected indefinitely to temperatures as high as 1600°F. without loss in efficiency. A calcined type of brick will withstand temperatures up to 2000°F.; and a press-formed calcined brick is capable of resisting temperatures mounting up to 2500°F. These bricks are subjected to heats of about 2800°F., which is just a little below the melting point of the material; but, even so, the structures of the diatoms are not destroyed. The purpose of the calcining is to burn any existing clay or organic matter.

Vast quantities of various fuels are burned for power, industrial, domestic, and allied purposes, and the primary object is to capture and utilize the largest possible measure of their contained heat units. To do this, heat must not be radiated from heated surfaces and dissipated into the surrounding air. It is to minimize such losses through effective insulation that the foregoing commodities are manufactured. Proper insulation can safeguard against fuel wastes totaling many millions of dollars annually. The skeletons of tiny diatoms deposited eons ago are aiding man to conserve heat and to make momentous monetary savings; and, paradoxically, the minute creatures contributing to these economies originated in the Arctic Ocean!

Diatomaceous earth, under the trade name of Celite, is growing steadily in importance as an ingredient in concrete, because so small an amount of it as three pounds to a bag of cement will effect a remarkable improvement in what is known as the "workability" of concrete or the ease with which it can be placed in the prescribed position. In the last analysis, a concrete may be lacking in uniformity, strength, watertightness, durability, and appearance if it be not sufficiently workable to form a homogeneous mass. Workability may be secured by using excessive quan-



USES OF DIATOMITE

This product of the skeletal remains of countless minute organisms is put to many and varied beneficial uses. As a filtrant its extreme fineness renders it far more effective than the best medium man can fabricate, and it is widely employed in the refining and purifying of liquids. The center picture shows a filtration unit for treating soya-bean oil.

Under the name of Celite, diatomite has numerous uses in the structural field. Added to concrete, it lubricates the ingredients and causes the mixture to flow freely. The sharp definition of the decorative details of the building shown on the right was insured in this manner. Celite likewise improves the quality of stucco mixtures for building finishes such as that used on the Villa Riviera, at Long Beach, Calif., which is pictured above.

tities of sand and water; but while the concrete will flow more freely the components will tend to separate and settle differently—producing segregation. A concrete of this sort is weak. Curiously, the addition of powdered diatomite lubricates the ingredients and causes the mixture to flow readily, to fill every part of a form, and to set with the different components distributed evenly throughout the mass. Celite concrete has been used in many great recent engineering undertakings, and it has also been employed to advantage in the erection of numerous buildings and other architectural creations. Celite also improves the qualities of mortars, stuccos, and plasters.

Perhaps the services of diatomite are brought more directly home to most of us through its utilization as a filtrant. This may range all the way from the filtration of serums, toxins, and other sterile fluids in the battle with disease to the refining of petroleum, not to mention the filtering of cottonseed, soya-bean, and other vegetable oils, sugars, fruit juices, chemicals, beverages, pharmaceutical preparations, lacquers, varnishes, etc. Indeed, there is a bewildering array of fluids that are now clarified at one stage or another by means of filtration; and properly prepared diatomaceous earth is peculiarly fitted for the removal of suspended matter composed of particles ranging down to those of ultramicroscopic size.

The glittering, crystalline lumps of sugar that sweeten our tea or coffee are what they are because the refiner knows that he can produce high-quality sugars only when he has clear, sparkling sirups from which to garner crystals; and whether the sugar be made from cane or beets, the sirup must be suitably filtered. Celite for this particular service is available in several grades to meet the different requirements of the sugar industry as well as of those other manufacturing activities referred to in the preceding paragraph. Indeed, the subject of filtration is so comprehensive that we can here only indicate its scope in general terms; but in all this essential work of removing waxes, suspended colloidal matter, and so-called impurities of many sorts, diatomaceous earth is thoroughly efficient and also economical. The infinitely tiny cells are the means of bringing about the desired degree of separation and yet, at the same time, they facilitate relatively rapid filtering. What is known as Filter-Cel has pores so small that the material will remove slimy or colloidal matter of less than 0.1 micron in size—a micron measuring 39/1,000,000 of an inch! The finest woven filter cloth is, by comparison, virtually an open mesh.

The practical value of diatomaceous filtrants is brought out in handling crude cottonseed oil, in which the use of Hyflo Super-Cel, for example, has led to a net profit of $39 for each tank car of the oil so treated. Again, the employment of bricks made of diatomaceous earth in an open-hearth steel furnace caused a saving of 51,000 gallons of fuel oil in the course of a year. After subtracting the cost of the insulating bricks, there was a net saving of $1,497.26. These are only some of the economies made possible through different forms of diatomaceous products.

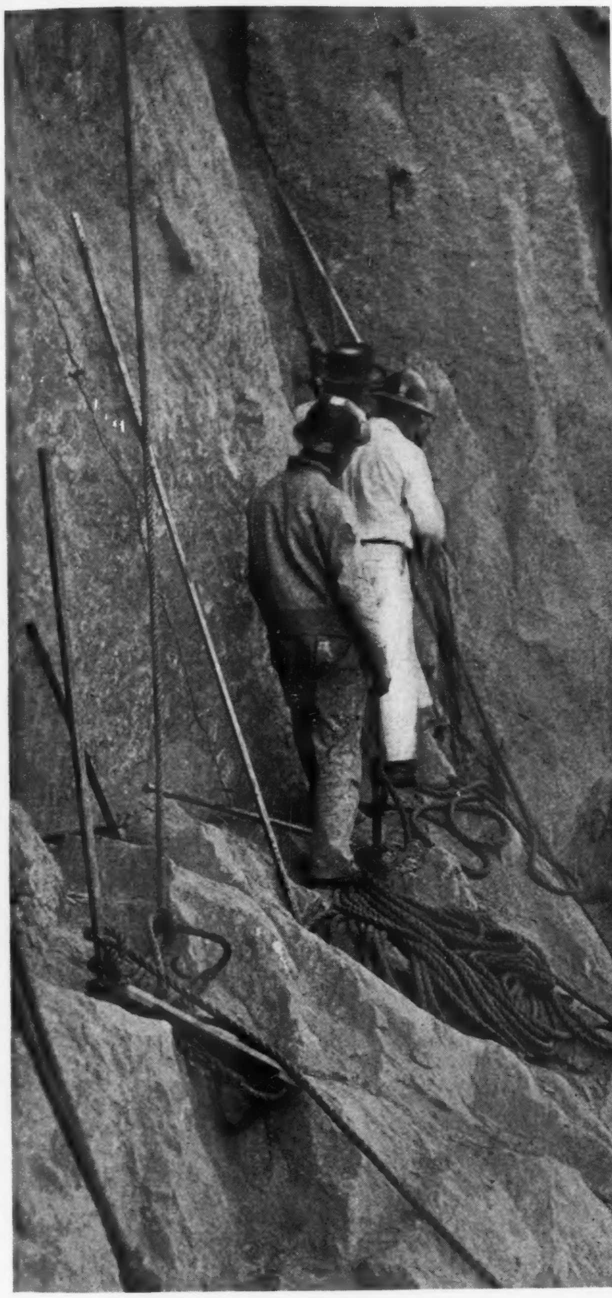
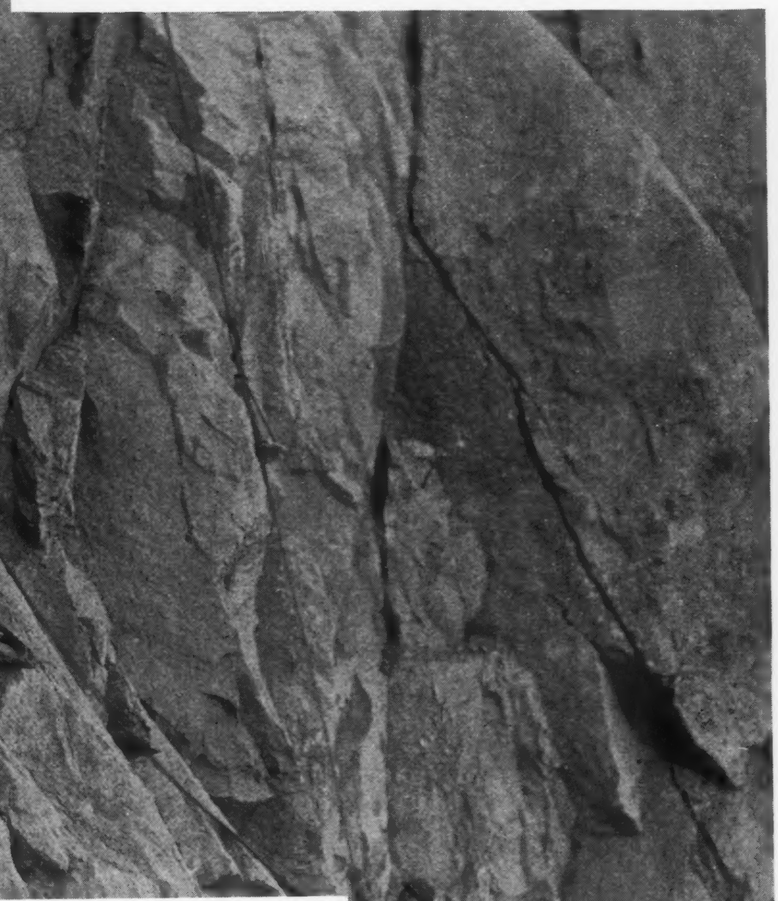
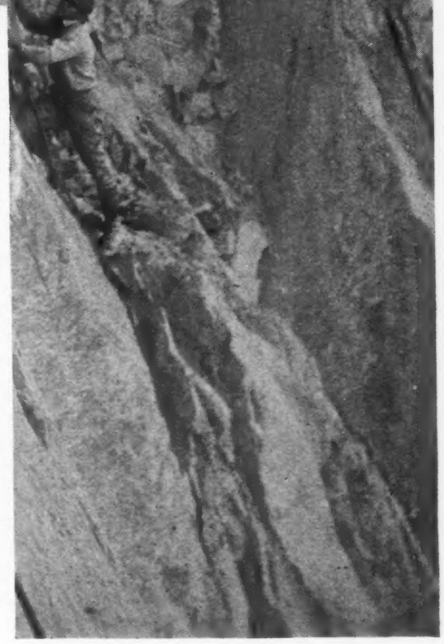
At one time, almost all our diatomite was produced in eastern states, notably in Maryland and Virginia, but now the bulk comes from the West. Our total output for the 3-year period 1930-32 amounted to 248,273 short tons valued at $3,902,126.

The little white hills of Lompoc, as the ancient Indians dubbed them, have a new significance today. Furthermore, they bear mute testimony to ocean currents and to crustal movements in the remote past, and they register how modern man has found varied and valuable uses for the extremely diminutive plant organisms that lived and died in that neighborhood while California was emerging from the depths of the sea.

Construction of the Boulder Dam*

Government Engineers and Surveyors Have Made a Notable Record on Exacting, Perilous Work

WESLEY R. NELSON†

ALPINEERING ON THE ANDESITE

A survey party on the steep cliff of the Nevada abutment while excavating in that area was in progress. A bos'n's chair used by one of the scalers working at this location appears at the left.

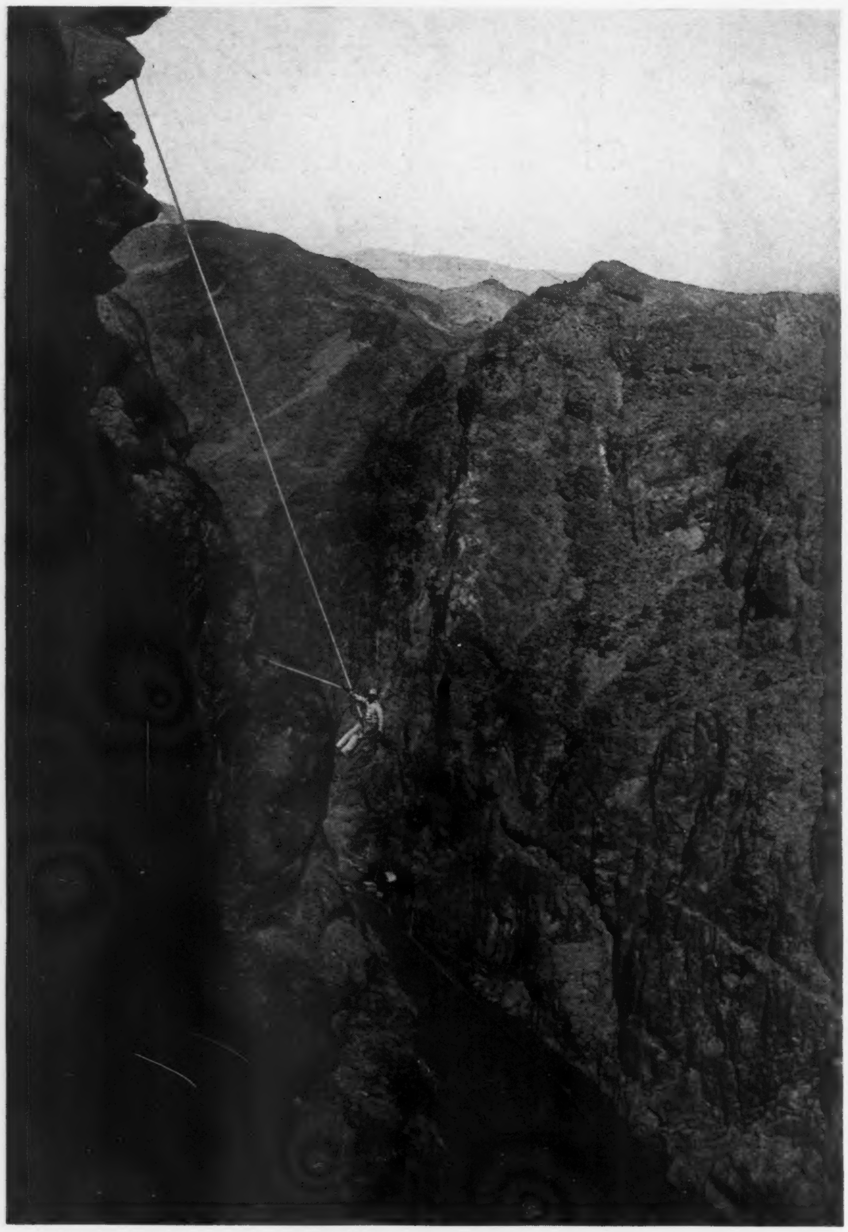
ADVANCING in the forefront of progress, taking the brunt of pioneering hardships, and at many times securing necessary data even at life's peril, will be found the explorer, the engineer, and the surveyor. Particularly is this true in the studies, examinations, and surveys conducted along the Colorado River, that turbulent stream which has drowned scores in its rapids and well earned its appellation of "The most dangerous river."

As Dr. Elwood Mead, Commissioner of the U. S. Bureau of Reclamation, has written, "The search for a suitable site for Boulder Dam went on for many years. Its history is filled with dramatic incidents. The early explorations were fraught with unknown dangers. Lives were lost, and there was always present a grave possibility that those who dared to traverse the gloomy canyons would never live to report their findings. Lieut. Joseph C. Ives of the U. S. Army, exploring the river in 1857, gave up with the conclusion that the Colorado, along the greater part of its way, should be forever unvisited and undisturbed.

"The survey of the dam site and reservoir was of unprecedented magnitude and difficulty. It involved coping with a river which, in the highest floods, rushed through the canyon with the speed of a railway train, and taking topography in more than

*Twentieth of a series of articles on the Colorado River and the building of the Boulder (formerly Hoover) Dam.

†Assistant Engineer, U. S. Bureau of Reclamation, Boulder Canyon Project.



ALL IN THE DAY'S WORK

Suspended from the canyon rim, a rodman or "rigger" indicates with a 15-foot pole a control point for transit shots from the opposite cliff. During the making of a topographic survey in 1932, rodmen in this manner descended cliffs as much as 1,000 feet high. Where there were overhangs or caves, these men sometimes had to swing themselves inward with a pendulumlike motion to furnish readings at recessed points. This survey party consisted of a chief, two transitmen, two rodmen, two recorders, two ropemen to lower the rodmen, one man in the canyon to warn workmen of falling dislodged rocks, and one signalman stationed between the two transits to establish communication between the transitmen and rodmen.

100 miles of canyon where precipitous cliffs 1,000 feet high and of indescribable ruggedness had to be scaled. Three lives were lost in this hazardous undertaking. Every phase of the work involved great danger, but the dimensions of the possible dam and reservoir had to be known. Then there had to be a topographic map.

"Anyone who views the canyon either from the top of the rim or from the river at the bottom, has a sense of the peril and hardship involved in fixing locations and making measurements on its cliffs. To have done this work by the old methods would have delayed beginning construction six months to a year. Resort was had to aerial surveys. This involved great hardship because of the intense summer heat and making observations at great differences in elevation."

Investigations by the United States Government of the potential resources of the Colorado have been in progress since 1850, when the sailing vessel *Invincible*, under the command of Lieut. George B. Derby, U. S. Army, penetrated the river from the Gulf of California to the mouth of the Gila River. Seven years later, Lieutenant Ives assembled a stern-wheeler, the *Explorer*, at the mouth of the Colorado and traveled on its waters to the upper end of Black Canyon where a sunken rock damaged the boat and prevented further progress upstream.

Maj. John Wesley Powell outfitted an expedition at Green River, Utah, in 1868-69, and descended the Green and Colorado rivers by boat to the mouth of the Virgin River, 35 miles upstream from Black Canyon. In 1870 Major Powell was placed in charge of an organization to make topographical and geological surveys along the Colorado and its tributaries. The survey, when completed, covered more than 100,000 square miles of territory.

The Department of the Interior, through the Bureau of Reclamation and the Geological Survey, has been making investigations and surveys on the Colorado River for the past 31 years, determining its characteristics, analyzing its resources with reference to the development of lands in its basin, and locating sites where the construction of dams is feasible from structural, geological, and economic standpoints. As a result of this work, irrigating water has been provided or supplemented for hundreds of thousands of acres of arable land, thousands of homes have been established, and millions of dollars have been added to the national wealth.

Notable among the irrigation projects that have been undertaken are the Grand Valley and Uncompahgre in Colorado; the Strawberry Valley in Utah; the Salt River in Arizona; and the Yuma in Arizona and California. Only one of these, the Yuma, secures water from the main Colorado in the lower basin. Several other irrigation projects have been developed in that section through private endeavor; but the inadequate flow of the river in some years, the heavy silt load it carries, and the destructive tendencies when in flood, have restricted the settlement of lands, burdened the promoters with costs amounting to millions of dollars for cleaning deposited silt out of canals, laterals, and ditches, and threatened complete inundation or destruction with a resultant loss of confidence and of credit.

With these facts in mind, special consideration was given to a dam site in the lower basin that would provide a large reservoir for the storage of water and silt, that would effectively protect the downstream areas from flood, and that could be constructed without burdening the benefited lands with a debt that could not be paid under existing agricultural conditions.

Parties of Government and private engineers that had traveled down the tortuous river had made mention of feasible dam sites at Boulder and Black canyons as far back as 1902. It was, however, not until 1919 that the late Arthur P. Davis, then director of the Reclamation Service, envisioned the possibility of power as an aid to the enterprise, and he courageously proceeded to plan a dam of unprecedented height and a reservoir of unprecedented capacity. Engineer-Geologist Homer Hamlin, in charge of a party sent out in 1920,

placed a stake to mark the place in Black Canyon recommended by the director for the building of a dam. That stake has since been found within a few feet of the axis of the dam now under construction.

In 1919, the U. S. Geological Survey was directed by the Secretary of the Interior to make a topographical survey of the proposed reservoir site upstream from Boulder Canyon, and to take elevations for the plotting of contours at 50-foot intervals from the river up to elevation 1,250. From such a survey could be calculated not only the volume of water backed up by dams with varying crest elevations but also the area of land that would be inundated.

The party that was organized for this purpose was compelled to use the river as a means of transportation, as the canyon-wall terrain was far too rough and precipitous for travel by land. The survey proved to be of a kind that taxed the endurance of all its members, and presented grave hazards and risks each day the work was carried forward.

The Colorado is notorious for its dangerous rapids that have blocked successful navigation of that stream since the first attempts were made 400 years ago. Torrential rains sweep bowlders from side canyons into and across the river channel, forming rock barriers over which the water breaks in a thousand cataracts or is turned in a mad frenzy toward the canyon walls, rushing by at the speed of a mill race. When large bowlders lie just beneath the surface, "holes" are formed on their downstream sides into which the water drops and churns in a roaring crescendo.

The party was able to portage past many of the rapids and to line the boats through at points where talus slopes jutted into the stream at the base of cliffs; but in many places the walls rose abruptly from the water's edge and the only route was through the rapids. The boats used on the expedition were generally about 25 feet in length and had hatches forward, amidships, and aft for supplies and equipment which were sheltered by tight-fitting hatch covers. When shooting rapids, the stern of the vessel was turned downstream, guided into the deepest water at the head of the rapids, and then relinquished to the current as the boatman fended off projecting rocks, dodged "holes" and whirlpools, kept the craft on an even keel, and headed downstream in a swift descent through the turbulent swirling waters and rock-strewn channel. A partial boatload of water was usually shipped in the passage, and boats were often overturned. Other dangers lurked in the swift rising floods; and the men had to be continually on the alert when encamped on the river shore because rains in the lower elevations or melting snows in the mountains were apt, during any month in the year, to precipitate a torrent, causing the water's surface to rise as much as a foot in an hour and doubling the flow in a day's time. Added to the ever-present perils of the river were the disagreeable weather

CLOSE CHECKING

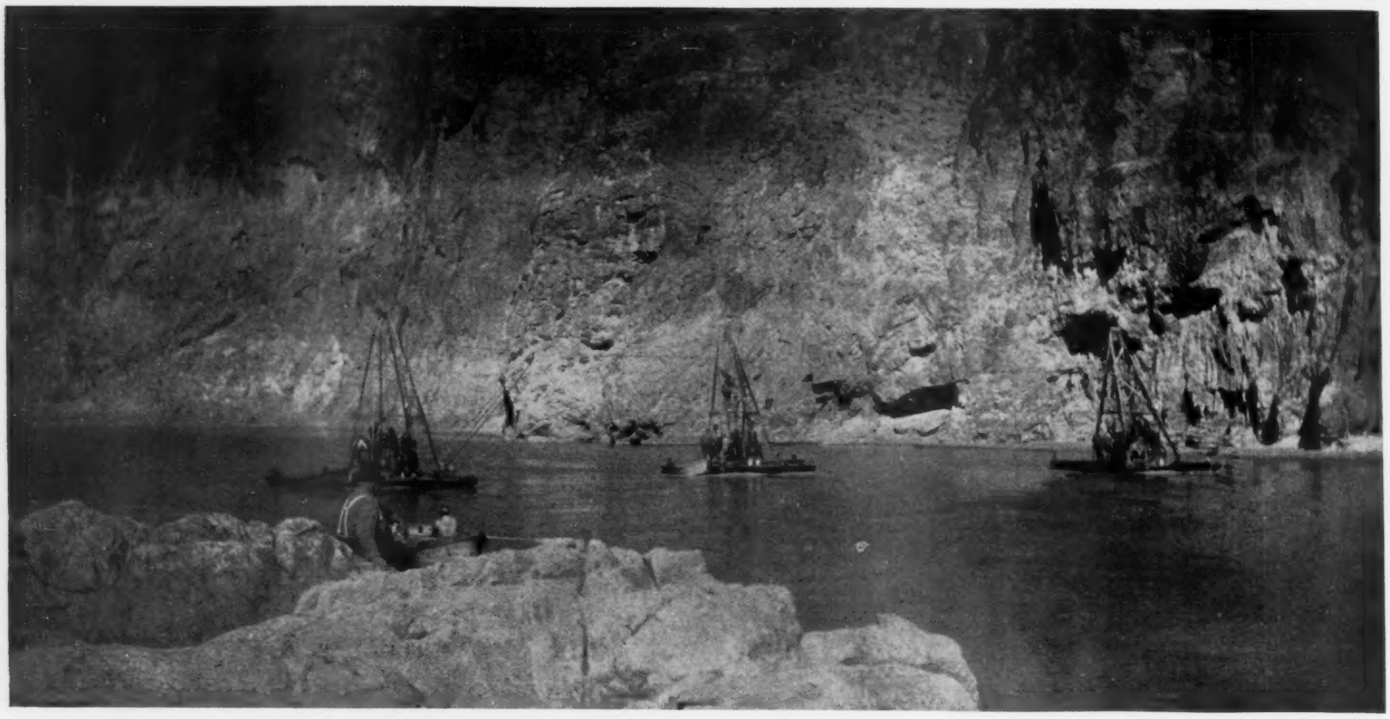
The stake shown was placed in 1920 by a survey party in charge of Engineer-Geologist Homer Hamlin to mark the location recommended for the construction of a dam in Black Canyon. It was found years later by engineers who fixed the axis of the Boulder Dam at the point indicated with white paint above and to the left of the stake.

conditions that existed in the desert region. The cold blasts of winter were followed by winds of high velocity in the spring, and these were succeeded by the furnacelike heat of the summer when thermometers registered as high as 128°F. in the shade.

As a result of recommendations made by the Bureau of Reclamation, based on these investigations and surveys, Congress in 1920 passed the Kincaid Act authorizing and instructing the Secretary of the Interior to make examinations and to report on the problems of the lower Colorado River.

Explorations of foundations by diamond-drilling were started in Boulder Canyon soon after under the direction of the superintendent of the Yuma Project. On January, 1921, they were taken in charge by Engineer Walker R. Young, who continued the work until May of that year when he was forced to suspend operations owing to high water. These investigations were resumed in the winter and spring of 1921-22, and completed in the same seasons of 1922-23.

With the exception of angle holes and a few other holes along the shore line, all the drilling was done from derricks mounted on barges. Each barge was constructed of two pontoons, 36 feet long, on which was laid a deck 15 feet wide. The barge was hung from cables spanning the waterway, and was moved to the shore when the river rose in flood. The drills, equipped with diamond bits, were rotated by 10-hp. gasoline en-



TEN YEARS BEFORE CONSTRUCTION BEGAN

Three barges equipped with diamond-drill rigs testing the rock beneath the river at Boulder Canyon in February, 1921. Investigations of possible dam sites went on for many years before the Black Canyon location was selected. The capriciousness for which the Colorado is noted rendered these activities highly dangerous at times.

gines. Holes were usually drilled on lines 200 feet apart and to depths as great as 200 feet extending 50 feet into solid rock.

The personnel at Boulder Canyon during the first drilling season numbered as many as 58 men; the camp consisted of 28 tents; and four barges were employed in the drilling operations. A group of flat-bottomed boats, several equipped with outboard motors, carried the men and supplies to the barges.

Drilling in the Colorado was never expected to be a sinecure; but it soon became evident that the river's power and strength had to be treated with respect, and that slight miscalculations might result disastrously, even have fatal consequences. Quoting from Engineer Young's report for February, 1921, to the Denver office: "Two men in a small boat were swept in front of and under barge No. 2 on the 22nd. Men and boat were recovered without loss. Man fell off of barge No. 1 on the 23rd, but caught a rope. As the night shift was leaving the C line for camp on the 28th their motor stopped working and the boat with four men was swept in front of and under barge No. 3. Three of the men clung to the barge, but the fourth went under. He was given up as lost, but was picked up about three hours later on the Arizona side of the Canyon by a boat sent down the river from camp. The boat and motor were lost."

At another time a barge broke loose from its cable, throwing three men overboard. Driftwood, carried so plentifully by the river, broke standpipes beneath the barges, or caused the latter to sink with a loss of all their equipment. Storms occurring in December, 1921, washed out road connections between the camp and St. Thomas, the nearest town where supplies were obtained; and the rise in the river resulting from the flood destroyed one barge and drowned one of the drillers.

In January, 1922, a camp was erected near the mouth of Black Canyon and investigations were started of the foundations at the upper dam site. A windstorm that arose soon after leveled the camp, blowing away most of the equipment even down to the floor boards of the tents. The camp was rebuilt and work continued until May. It was then suspended for the summer, resumed in September, and completed on April 24, 1923.

At the time drilling was in progress, topographical surveys were being conducted in the river channel and on the sheer 1,000-foot-high canyon walls to secure data for the plotting of maps and the subsequent designing and locating of the proposed dam and related features. Trails were cut and blasted along the cliffs for this work, and ladders were erected to reach otherwise inaccessible places. During those surveys, triangulation points were established and tied into preceding land surveys. Mean sea level was used as the datum for elevations, starting from bench marks set on a line of levels run by the Geological Survey from Hackberry, Ariz., to Moapa, Nev., with a loop line extending to St. Thomas. Supplementing the surveys, geological investigations were made of the reservoir area and of the Boulder and Black canyon dam sites, suitable gravel deposits were located, and the region around each dam site studied with reference to details of proposed construction, accessibility, and related features. All data were assembled by the Bureau of Reclamation; and in 1924 a report was submitted to Congress recommending the building of a concrete arch-gravity-type dam in Black Canyon.

The principal reasons for preferring Black Canyon to Boulder Canyon were: greater accessibility, lesser maximum distance to bedrock, larger reservoir area, lesser amount of concrete required for the same height of dam, and better geological conditions particularly in relation to faults.

Then followed a period of several years when little work was in progress in or near Black Canyon, as the project was under discussion in Congress and legislative matters and irrigation problems were being straightened out in the states of the Colorado River basin. After these matters had been settled, the Boulder Canyon Project Act was passed by Congress; power contracts were negotiated to insure repayment of construction charges in 50 years; and the first appropriations were made on July 3, 1930.

Engineers of the Bureau of Reclamation and consulting boards had weighed all available information and determined that Black Canyon was the more feasible site for the construction of the dam. The preliminary surveys of that site, however, had extended only far enough to provide data for the design of a dam. As further information about the region for several miles around the dam site and more details

BLACK CANYON

This view of the dam site, guarded by forbidding ramparts of lava, conveys a fair idea of the difficulties that confronted the preliminary engineering parties.

REAL BOULDER DAM PIONEERS

Personnel of the Boulder Canyon survey camp in February, 1921. This picture was made by the chief of the party, Walker R. Young, whose photograph appears below. Mr. Young has been intimately connected with the Boulder Canyon Project for thirteen years, and is seeing the job through as construction engineer for the Bureau of Reclamation.

regarding the canyon walls were desired with a minimum of delay, additional topographic surveys were started by airplane and from the ground within two days after the appropriations had been made. These were completed within two months. The surveys by airplane were contracted for, and covered an area of 96 square miles around the dam site: those by ground methods covered approximately 8,000,000 square feet, as projected on a vertical plane, of the precipitous canyon walls. A mosaic and topographic maps were prepared from this work, using special equipment based on the principles of stereoscopic scrutiny.

As construction got underway on the project, the demand for surveys became greater and greater. From one survey crew the number grew to five, ten, and then to fourteen, the personnel from 5 to 60. The work was extremely fatiguing, as well as hazardous. Ladders were built to reach some locations, but others were found inaccessible except by lowering men with ropes. To ascend or descend the canyon walls by ordinary means usually required long hikes over trails that were few and far between.

Springtime winds, causing discomfort and danger by carrying sharp sand and by dislodging pebbles and rocks from the canyon walls, were followed by the intense heat of the summer. During July the mean temperature in the shade was 107.4°F. On two days the maximum temperature was 128°, and for two-thirds of the month the thermometer at some time during the

UNDERGROUND WORK

A drill carriage in the Arizona penstock header tunnel, showing surveyors measuring the excavated section with "wheel" and tape. At the height of tunneling activities, Government engineers had to make measurements and supply data at upwards of fifteen headings. In the larger bores, guide marks for the next round were painted in white on the drilling face after each blast.

day registered above 120°. Thermometers broke at 140°, rocks and metal burned the hands, and the canyon walls reflecting the sun's rays created an inferno in the depths below. All measurements required temperature corrections for chaining, surveying instruments had to be shaded, and heat waves made reading of record or point impossible for any except short distances. Surveying was started at 2 a.m. and stopped at 11 a.m. The men worked with little clothing—only shoes, trousers, and helmets. Reflecting the loyalty of the men to their organization and indicating the careful manner in which the survey was performed, it is of interest to note that none quit work on account of its arduous character, none was discharged, and none was killed or seriously injured once construction was in progress.

Great ingenuity and initiative were required in locating the numerous structures at the dam site, in measuring the quantities that were to furnish the basis for monthly payments to the contractors, and in making the check surveys after construction was finished. Tunnel headings were painted after each round of blasting, thus outlining the boundaries for the following shot. Excavation lines were painted on the canyon walls at the sites of the intake towers, spillways, valve houses, cofferdams, and the main dam structure. These were remarked when destroyed by blasts; and as an excavation approached final lines, the rocks remaining in that section were outlined for trimming operations. In some of the tunnels the usual underground surveying obstacles were accentuated by the fact that curves connecting the center lines of intersecting tunnels were neither in a vertical nor a horizontal plane. Excavations were outlined in such cases by 3-dimension graphs prepared in the field office.

The phototopographic data were not sufficiently accurate nor detailed for all purposes, hence, in 1932, a survey of the walls of Black Canyon was instituted so as to secure information for the accurate plotting of a topographic map to a scale of 20 feet to the inch.

An unusual procedure was adopted to obtain the desired data. Two transits were set up on one canyon wall at points of known location, elevation, and back sight. The rodman, equipped with a 15-foot flagpole, was lowered by rope down the opposite wall, in places nearly 1,000 feet high, and stopped at intervals to enable him to indicate with the pole the points of control for the topographic data. After reaching the canyon floor, he returned to the rim by trail or by climbing a rope, while another rodman was lowered at an adjacent location. Because of overhanging cliffs, the rodmen were required, in many instances, to swing themselves inward in pendulumlike manner in order to reach otherwise inaccessible points. As an indication of the precipitous nature of the canyon and of the exactitude of the survey, 4,000 transit shots were taken in a horizontal area of 320x660 feet, the longer dimension extending along the canyon and the other dimension toward the river. The maximum difference in elevation in this section amounted to 600 feet.

The surveyor accomplishes his important task in a quiet and unobtrusive manner, and the casual observer seldom realizes that all the construction operations are based on his maps. When watching the high scalers at work on the canyon walls, the tunnels being driven through hard rock toward definite objectives, or the concrete being poured in channel linings, intricate structures or dam columns, it is well to remember that the surveyors were there before the work was started, are there to locate and to guide construction, and will follow the project through to its conclusion.

The Bureau of Reclamation, which has so thoroughly investigated the characteristics and potential resources of the Colorado River, has as its administrative head Dr. Elwood Mead, Commissioner, at Washington, D. C. All engineering and construction is supervised from the Denver, Colo., office, where R. F. Walter is chief engineer, S. O. Harper is assistant chief engineer, and J. L. Savage is chief designing engineer. Walker R. Young, construction engineer at Boulder City, Nev., is in direct charge of field operations at Boulder Dam.

Air Cushioning High-Pressure Oil Pipe Lines

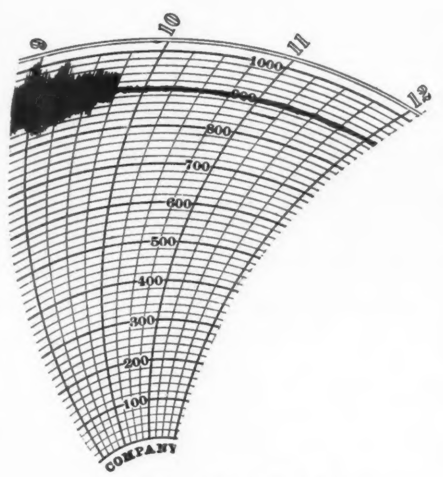
ELTON STERRETT

MAIN pipe lines delivering crude petroleum from oil fields to distant distribution points often work under pressures all but incredible to persons not directly connected with the industry. In the great East Texas field, for instance, discharge pressures at the pump range as high as 1,000 pounds per square inch, and this not in small-size pipe but in mains up to 8 inches in diameter.

Where this oil is moved with plunger pumps, the sudden rise in pressure as each set of discharge valves opens starts an impulse which is readily discernible on a sensitive pressure gauge 40 miles down the line and which can be detected with ear to pipe at nearly twice that distance. If this hammering effect is allowed to continue unchecked, crystallization is sure to occur at river clamps, junctions, welds, or other points where free expansion of the pipe wall is restrained.

The most practical method of controlling this severe plunger pound is through the installation of air chambers—"air bottles" to pipe-line operators—on each pump discharge line as close to the pump as convenient. The effect of such cushioning in smoothing out pulsations is shown in the accompanying reproduction of a section of a pressure chart that covers operations of a main-line pumping plant during a 3-hour morning period. Up to 9:20 a.m. two independently driven and nonsynchronized 5½x24-inch duplex pumps were on the line, pumping approximately 1,000 barrels an hour against the pressure indicated, and with no air cushioning. At 9:20 o'clock the air chamber on one pump was tied in, lowering the pressure peaks for pump strokes by about 40 pounds and eliminating almost half the false low-pressure nodes caused by inertia of the recording device. At 9:45 o'clock the second air bottle was put on, resulting in practically instantaneous smoothing of the ragged line to an even curve. Owing to the inertia effect of the recorder pen, it was impossible, before cushioning the pumps, to open fully the control valve to the gauge, for when that was done the pen swept completely off the ruled space, vibrating too rapidly to record its travel, and was unable to return in time to record the next peak pressure. The chart, then, may be considered as showing only a portion of the pressure fluctuation set up by uncushioned plunger pumps. The control valve was untouched during the experiment to keep from altering test conditions.

Because of the high pressures carried, compressed air must be supplied to these cushioning chambers, as the rise from atmospheric to line pressure would compress the original volume of air—if taken in at



THE CHART'S STORY

The vibration in a pipe line before and after cushioning was applied is shown here. At 9:20 a.m. one of the two pumps was connected with an air bottle, and at 9:45 o'clock the second one was similarly tied in.

atmospheric pressure—to such a small space that it could be of little value in cushioning the strokes.

Most oil-field internal-combustion power units are started with compressed air, so there is usually available somewhere around each pumping station at least a single-stage compressor, delivering air at pressures up to 250 pounds per square inch, for charging the cushioning chambers.

The scheme of charging may readily be understood from an accompanying sketch. By first cutting the bottle off the high-pressure discharge line by closing the valve "G", the vent or blow-down valve "V" is opened and compressed air is admitted through valve "A". This forces out any oil within the cushioning cylinder above the outlet level "L". The vent valve is then closed, the pressure built up to the maximum attainable by the compressor, and valve "A" is closed.

When attempting to put this charged bottle back in service by opening valve "G", explosions sometimes occur. A study of what theoretically takes place within the cushioning chamber explains why the danger of explosion is present and suggests a simple means of removing the hazard.

Assuming that the oil level is at "L" under compressor pressure and rises to "H" when pipe-line pressure is admitted, it is obvious that the air volume is reduced—considering the bottle as a true cylinder including the slight hemispherical space in the dome—and the pressure is increased in proportion to the respective distances of "L" and "H" from the top. In other words, the confined air is almost instantaneously compressed from a pressure of around 250 pounds per square inch to one approximately four times as great. Since the interior of the cylinder is virtually sure to be coated with paraffin and thus will approach a condition of practically complete heat insulation, it is reasonable to consider this compression as adiabatic; and it is accordingly easy to compute the theoretical temperature of the confined air at the instant maximum pressure is reached. These figures are given in Table 1.

It should be noted that in arriving at those figures three conditions of outside temperature were considered, the highest being less than is frequently recorded on exposed metal surfaces during hot summer days. Also it should be pointed out that the practice is to compress air into storage tanks and that it is held in these long enough for it to cool to the temperature of the surrounding atmosphere before it is used.

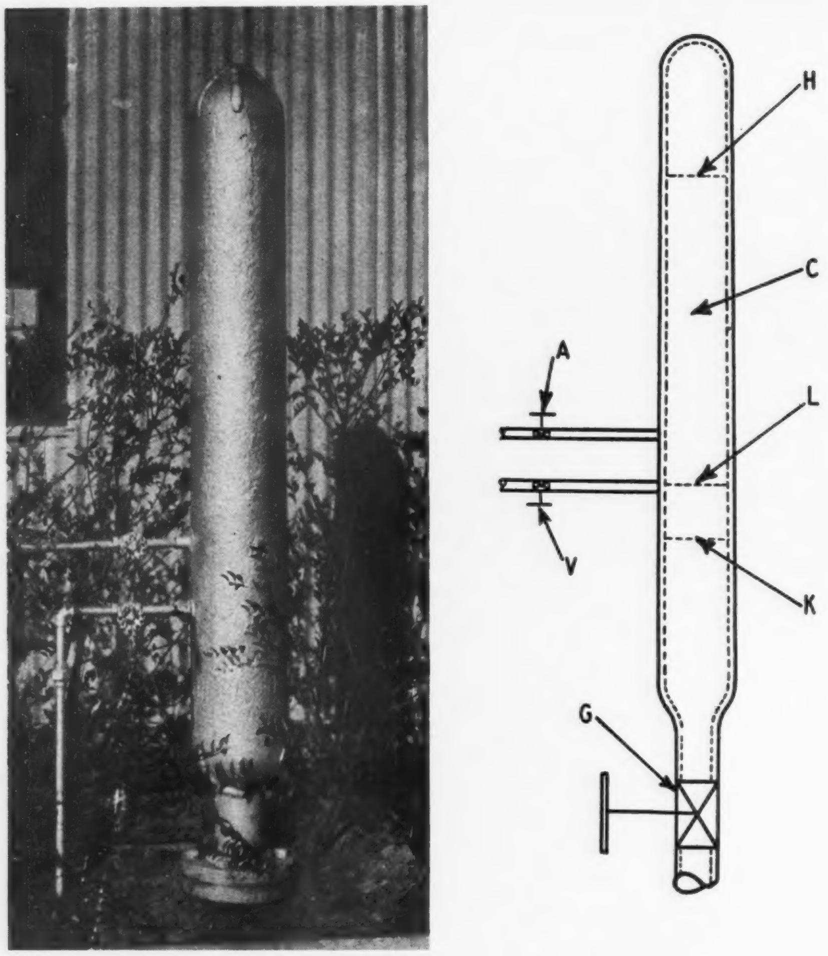
Inasmuch as there is always more or less highly inflammable vapor present no matter what the pressure on the oil, and as this gas is intimately mixed with the air within the bottle, it requires no stretch of the imagination to picture what takes place within the cylinder when line pressure is admitted too rapidly for the heat generated by the compression of the confined air to be dissipated through the cylinder walls. The bottle becomes in effect a diesel-engine cylinder, and when a temperature high enough to ignite the mixed vapor is reached, an explosion must occur. If the valve "G" is open sufficiently, the force of

TABLE 1 OF PRESSURES AND RESULTANT TEMPERATURES

Outside Temp. Degrees	Initial Press. Lbs. per sq. in.	Final Press. Lbs. per sq. in.	Resultant Temp. Degrees F.
60	250	1000	308
90	250	1000	351
120	250	1000	397

TABLE 2 OF PRESSURES AND RESULTANT TEMPERATURES

Outside Temp. Degrees	Initial Press. Lbs. per sq. in.	Final Press. Lbs. per sq. in.	Resultant Temp. Degrees F.
60	1200	1000	33
90	1200	1000	62
120	1200	1000	90



DAMPENING PIPE-LINE PULSATIONS

The photograph shows a typical "air bottle" in which compressed air is used to cushion the vibrations set up in oil pipe lines by high-pressure plunger pumps. The sectional drawing indicates what takes place in the bottle under the various operating conditions discussed by the author. Following is a key to the lettered designations: C, air-cushion cylinder; A, air-charging valve; G, main-line gate; L, vented air-oil level; H, charged air-oil level; K, supercharged air-oil level; V, blow-down valve.

this explosion may exert itself on the moving column of oil in the main line, possibly without serious damage; but if the valve is barely cracked, the suddenly generated pressure of the explosion is confined within the bottle and the steel shell is ruptured, causing burning oil under high pressure to be sprayed over everything in the vicinity.

Having determined the nature of the phenomenon by applying the principles of adiabatic compression, a little further investigation along the same line suggests a simple and safe way out of the difficulty. It is necessary only to make sure that the temperature within the cushioning cylinder does not rise during the time the bottle is being put on the line. As the cylinder wall must be of sufficient thickness to withstand the high pressure carried, water-jacketing or the use of cooling fins is unavailing, owing to the time required for the generated heat to pass through the insulating paraffin deposit and the comparatively thick steel wall.

A much simpler method instantly offers itself. Since compression of air is exothermic or heat producing, expansion of air must be equally endothermic, or heat absorbing. In consequence of this fact, if the confined air above the initial oil level "L" can be expanded as line pressure is met, a drop in temperature may be expected.

Now let us assume that air compressed to 1,200 pounds per square inch, instead of 250 pounds, is used for charging the bottle while it is cut off the line. Since this pressure is 200 pounds greater than the pressure of the oil being pumped, expansion of the imprisoned air will occur within the cushioning cylinder when valve "G" is opened, and the oil-air level will be forced downward to "K". As a consequence of this expansion, the temperature of the oil-vapor mixture will be lowered below that of the surrounding air, and there will be no more danger of an explosion resulting from opening valve "G" than from opening any other valve in the oil-discharge main line. This temperature drop is apparent in Table 2.

To protect the air chambers, therefore, only a slight change in plant set-up is indicated. As starting air is but infrequently required, only a small multi-stage compressor need be installed where a single-stage unit has been furnished as original equipment, and high-pressure storage substituted for the low-pressure tanks. A high-pressure line of small diameter direct to the air bottles on the crude-oil delivery line will reduce expansion loss while charging; and a pressure-regulating device on the air lines to the engines will make sure that they will never be subjected to more than their designed maximum starting pressure.

The cost of a multi-stage compressor may be considered extremely economical insurance against possible plant damage that may occur where the low-pressure method of charging is used. Or, viewing the proposition from outside the pumping-station angle, the property damage and oil loss incurred through but one break of an imperfectly cushioned and thus prematurely crystallized main line would probably exceed by far the cost of the entire air-compressing equipment.

WASHINGTON MONUMENT NEEDS STRENGTHENING

WASHINGTON Monument is top-heavy. This is evidenced, says the United States Bureau of Standards, by the spalling, in the lower part of the structure, of the marble face along the horizontal mortar joints. To determine something of the degree of this excess burden carried by the base, the bureau made some tests with marble of the same variety which has been exposed to the weather for 70 years. These showed that the stone has a compressive strength of more than 5,000 pounds per square inch; and it was estimated that, with a uniform distribution of the load and with maximum wind pressure, the lower part of the monument should at no point be subjected to a stress in excess of 700 pounds. Actual conditions, however, indicate that it is much more than that.

Work on the structure, which was completed in 1884, was begun in 1848, and no records are available concerning its method of construction in the early days. It is not known, for example, whether there is a rubble-masonry filling between the inner and outer ashlar walls. If lacking, that might explain the unequal distribution of the load. In that case, the condition could, perhaps, be remedied by making up the deficiency with mortar forced under air pressure into the interstices in the base. The exterior of the monument is now undergoing cleaning and repair.

TWO HUGE JOBS DONE

AMONG the significant events of the past month were the openings of two great conduits located on opposite sides of the earth and designed to convey two unlike but necessary fluids. On October 14, petroleum from Kirkuk, in northern Iraq, began flowing through 620 miles of underground pipe to Haifa, Palestine, on the Mediterranean Sea. Just two weeks later water from the high Sierras reached San Francisco through the Hetch Hetchy system of reservoirs, tunnels, and flumes. Two vast engineering undertakings, both daringly conceived and efficiently executed, were thus formally consummated. Each represents a notable conquest of natural obstacles by man.

Almost entirely surrounded by water, San Francisco went 170 miles into the hinterland to safeguard its future domestic supply of this vital liquid. Physical, economic, and legal barriers had to be surmounted. Nearly 82 miles of tunnels had to be driven, including one 25-mile continuous bore that marks a record for that class of construction. Unstable ground and lethal gases continually harassed the workers and confounded the engineers, but the work went on. The only sad note attending the ceremonies in celebration of the successful conclusion of the enterprise was the absence of M. M. O'Shaughnessy, who, as chief of the engineering staff, indefatigably carried on for more than twenty years, undismayed by the countless vexations and delays. Mr. O'Shaughnessy died with his work substantially completed. His name has been given to the dam across the Tuolumne River that forms Hetch Hetchy Reservoir and will endure for generations to come. Approximately $100,000,000 has been spent on the Hetch Hetchy system.

The Kirkuk-Haifa pipe line extends across virtually uncharted desert and mountain waste. A companion line parallels it for 156 miles from Kirkuk, then turns northward at Haditha, and crosses Syria to Tripoli. Together, these two 12-inch conduits can carry 28,322,000 barrels or 4,500,000 tons of oil annually. Of international sponsorship, the construction was speeded to completion by concentrating men and machinery at many locations. The cost of the bifurcated line was about $50,000,000.

COMPRESSED-AIR LOCOMOTIVES

ENGINEERS are giving increased thought to the possibility of propelling locomotives economically and advantageously with compressed air, and it is predicted that this idea will be thoroughly tested during the next few years. Haulage engines with reservoirs that were periodically charged with high-pressure air were once extensively used in mines, and some are still in service. The next natural step was to develop locomotives that carried their own compressors, but there was no economical way of applying this principle until the advent of the internal-combustion engine.

With the coming of the diesel engine, ideas of propulsion turned in another direction, with the result that oil-electric locomotives have gained an established place in our transportation systems. Meanwhile, some experiments have been carried on with diesel-compressed-air locomotives, but they have not been extensive enough to warrant drawing definite conclusions. Those who have worked out the thermodynamics of such a mechanism claim that it has several advantages and that the chief problem is one of developing designs that will effectively utilize its inherent potentialities. The fact that some of the diesel-engine heat can be used to expand the air before it is utilized in the locomotive cylinders opens up attractive possibilities, and points to the employment of a high percentage of the total power input in useful work. Efficient direct-driven oil-engine compressors have already been developed, and this adds still further to the interesting prospective features of this type of tractive unit.

THE METHUSELAH OF ROCKS

SLATE may be said to run the gamut of human life. As mere youngsters, we write upon it in school. When we die, we may be confined in a vault composed of it. During the interim we spend much of our time in buildings roofed with it and use many objects of which it constitutes a part.

To a greater degree than any other stone, slate has the quality of cleavage which enables it to be split into thin, smooth sheets. This characteristic arises from the manner of its formation. Originally clay, it has been metamorphosed by heat and pressure until, in some cases, only 2 or 3 per cent of it remains clay. The rest of it has been transformed into mica, chlorite, quartz, and other minerals. The flat, tabular crystals of mica and chlorite have arranged themselves in the same plane, and the result is the remarkable cleavage.

Pennsylvania is the leading source of slate in the United States, with Vermont second. Total United States production dropped from a valuation of $11,472,291 in 1928 to one of $3,104,300 in 1932. There are less expensive substitutes for slate in everyone of its important fields of application, and the increased adoption of these during the depression years has accentuated the decline in its consumption. To secure wider employment of this product, slate producers have recently improved quarrying and milling processes to reduce costs, and have also taken steps to classify products to indicate quality more clearly than in the past. Particular progress has been made in the roofing-slate industry, as recounted in an article in this issue.

Roofing slate, which normally accounts for about one-half of the country's output, is amazing in point of its endurance. No other natural or artificial material of equal cost and workability can compare with it. Slate roofs have been in service in the United States for 200 years without showing deterioration, while in Europe there are some that were laid from 800 to 1,200 years ago.

All About Indicators

"THE indicator is an old and versatile engineering instrument. In its original conception it was intended to aid the development of the steam engine, and in this field it has performed important services. The theory of the steam engine, and also that of the gas engine, as well as of pumps and compressors, has been largely built up on information obtained by means of the indicator. In the development of our piston-type prime movers from the wasteful, slow-moving and heavy engines of a century ago to the economical, high-speed and light engines of today the indicator has played a substantial part.

"Owing to the wide variety of its uses the indicator is an indispensable piece of equipment in most engineering investigations involving the measurement of forces and motions. A great deal of ingenuity and painstaking research have been expended in bringing it to its present perfection and in adapting it to a variety of purposes.

"The purpose of this book is to present the history, theory, and construction of the many forms of the pressure indicator from its inception to the present day; and the information it contains should prove useful in every shop and laboratory where variable pressures have to be known."

The Engine Indicator, Its Design, Theory, and Special Applications, an illustrated, 240-page book by Kalman J. DeJuhasz, assistant professor of engineering research at The Pennsylvania State College. Published by Instruments Publishing Company, 330 West 42nd Street, New York, N. Y. Price, including a year's subscription to the magazine *Instruments*, $3.50.

* * *

The Stone Industries

"STONE, the foundation and superstructure of the everlasting hills, is the most abundant of all material things. It is the earth itself on which we live.

"Remarkable progress has been made in the quarrying and utilization of stone. Its application to practical use was one of the oldest human activities, extending far back before the earliest records, to the 'stone age.' Neolithic man, using a crooked reindeer antler as a mining tool, dug flint balls from the chalk cliffs of England and shaped them into spearheads or other implements. During later periods American cliff dwellers constructed crude homes with walls of stone. The slow progress through long ages from these primitive beginnings makes interesting chapters in ancient history but has little bearing on the stone quarrying of today. Development of the industries in their present scope has been comparatively recent. From caverns and sheltering slabs of rock, constituting the earliest human habitations, to stately mansions of cut and polished stone is a long journey, and every step of progress has been marked by accelerated speed. Thus, although the industries have existed for many centuries, the greatest advances in manufacture and use have been crowded into the past 50 years. To give a true picture of the status of these industries today is the purpose of this book."

From the introduction to *The Stone Industries*, by Oliver Bowles, supervising engineer, Building Materials Section, United States Bureau of Mines. Published by McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York, N. Y. Price, $5.00.

* * *

What Does It Cost?

"MANUFACTURING progress, by reason of its intensive development, has brought production and costs into the positions of major importance. They now rest securely on an accepted body of principles and practice whereby orderly, effective operation can be planned for and maintained. The situation thus created demands organized information, hence the *Cost and Production Handbook*.

"Its purpose is to give in one reference volume practical working information on industrial operation for the benefit and assistance of everyone engaged in manufacturing, whether in a shop or an office position. It is the first major work to unite the two all-essential viewpoints of cost and production which merge into the objective of producing to a cost. Thus it presents, on the one hand, cost accounting to control costs, and, on the other, production control to reduce costs.

"The handbook has been created by a board of 80 contributing and consulting editors. Each member of this group has special qualifications for the writing or reviewing which he has done."

The foregoing are quotations from the preface of *Cost and Production Handbook*, a volume of 1,544 pages, edited by L. P. Alford, M. E., Dr. Eng., and published by The Ronald Press Company, 15 East 26th Street, New York, N. Y. Price, $7.50.

* * *

The Farm Chemurgic

"IN 1913, the Haber-Bosch plant at Oppau, Germany, began the production of synthetic ammonia from hydrogen and atmospheric nitrogen at the rate of about 7,000 tons annually. This small plant made the World War possible. By 1928 Germany's production of fixed nitrogen exceeded 400,000 tons per year, which amount exceeds the fixed nitrogen in the total annual export of sodium nitrate from Chile. Today Germany can produce 1,000,000 tons of fixed nitrogen annually, and the rest of the world can together synthesize about the same quantity. The Haber-Bosch process gives to man unlimited command of explosives and fertilizers. Through it the natural occurring nitrogenous fertilizers are rendered entirely superfluous.

"In dyes, artificial fiber, synthetic plastics, and synthetic ammonia, as well as the numerous lesser discoveries, the labor and habits of more than 25 per cent of the population in Europe and America have been rendered futile.

"The great chemical revolution came upon us through the replacement of naturally grown chemical products by those of synthetic chemical manufacture. Millions of men upon millions of acres witnessed their means of livelihood pass out from under them. These acres, once under cultivation of strictly chemical products for other than food industries, received no attention by way of introduction of yet newer and more promising chemical flora. The farmers were left to drift."

The foregoing are passages from an absorbing and enlightening book, *The Farm Chemurgic*, by William J. Hale, research consultant to the Dow Chemical Company. Published by The Stratford Company, 289 Congress Street, Boston, Mass. Price, $2.00.

* * *

The Amateur Machinist

"FOR the purpose of training your hand and brain to do teamwork, nothing is better or more profitable that I know of than to use tools, especially machine tools. Whatsoever your vocation may be, if you are at all mechanically inclined you should by all means get some hand tools and a lathe. The better the latter the better the work you can do on it, and, it follows, the greater the pleasure and the profit that will accrue to you.

"It may interest you to know that the men who have done most to give us time- and labor-saving mechanisms and to provide comfort and entertainment devices were either amateur or skilled machinists. A few of the many were Eli Whitney, who invented the cotton gin and made firearms by the interchangeable system of parts; James Watt, who invented the steam engine; Robert Fulton, who invented the steamboat; and George Stevenson, who invented the locomotive. Then there were Cyrus H. McCormick, the inventor of the harvesting machine; Elias Howe, inventor of the sewing machine; George Westinghouse, inventor of the air brake; Wilbur and Orville Wright, inventors of the airplane; Thomas A. Edison; and last and greatest of all, Henry Ford, who popularized the motor car."

These are excerpts from the author's foreword to *The Amateur Machinist*, an illustrated book of 300 pages written by A. Frederick Collins and published by D. Appleton-Century Company, New York, N. Y. Price, $2.00.